RESEARCH ARTICLE

Role of Fungi: as Ligno-cellulosic Waste Biodegrader of Agricultural waste (Paddy Straw)

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Abstract

In nature cellulose, hemicellulose and lignin are major source of plant biomass; therefore their recycling is indispensable for the carbon cycle. Each polymer degraded by a variety of microorganisms which produce a number of enzymes that work on waste material. For the present research work agricultural waste such as paddy straw were selected which was good source of lingo-cellulose content. Paddy straws were inoculated with fungal strains such as *Pleurotus sajor-caju, Trichoderma harzianum* and *Aspergillus niger and Chaetomium globosum* and allow composting process for 40 days with different combination of fungal strains. Temperature and moisture content 60-80% maintained throughout the experiment. Analysis of initial, control and compost samples showed degradation of cellulose, hemicellulose and lignin content. Cellulose decreased from 31.10% to 13.38%, hemicellulose 15% to 7.4% and lignin 14.30% to 3.35%. In the future, processes that use lingo-cellulytic enzymes or are based on microorganisms could lead to new, environment friendly technologies. This study suggests that agricultural wastes could be converted into some value added products such as compost.

Keywords: Cellulose, hemicellulose, lignin, composting, microorganisms

INTRODUCTION

In recent years, human activities have reached such a point of progress that the recycling capacity of nature has been exceeded, and the accumulation of waste has become a serious environmental and economic problem. The increasing rate of agricultural and agro-industrial waste due to the large scale of urbanization and a consequence of economic development has become a problem that produces the huge quantities of waste in India and causes a serious environmental problem which is difficult for management.

The increasing rate at which organic wastes are generated has become a problem for disposal and/or management. Therefore, the study related on safe reuse and management of agricultural waste is important. According to Appelhof (1981), the appropriate disposal of waste should involve both maximum cost effective recovery of recyclable constituents and transformation of non-recoverable material into forms, which do not present environmental hazards.

Each year human, livestock and crop produce approximately 38 billion metric tons of organic waste worldwide. Disposal and environmental friendly management of these wastes has become a global priority. According to a conservative estimation, around 600 to 700 million tons (mt) of agricultural waste (including 272 mt of crop residues) are available in India every year, but most of it remains unutilized.

Crop residues are generated in large quantities and constitute an abundant but underutilized source of renewable biomass in agriculture. The amount of crop residues available in India is estimated to be approximately 620 million (Pandey *et al*., 2009). Half the quantity of agro-residues thus produced finds use as roofing material, animal feed, fuel and packing material, while the other half is disposed of by burning in the field. Burning agro-residues in the field is considered a cheap and easy means of disposal of excess residues. This practice appends to air pollution, increases soil erosion and decreases the efficacy of soil-applied herbicides like isoproturon (Walia *et al*., 1999).

Composting is a controlled biological decomposition process that converts organic matter to a stable, humus-like product and the process depend upon microorganisms, which utilize decomposable organic waste both as an energy and food source (Sajnanath and Sushama, 2004).

Different wastes contain high concentrations of easily degradable organic substances with high moisture content and high density. Wood and straw which has approximately 40% cellulose, 20-30% hemicelluloses and lignin (Sjostrom, 1993) is difficult to breakdown in a normal composting process and can take considerable period of time. Among the fungi, white-rot, brown rot and soft-rot fungi are more capable of degrading cellulose materials. Thus, the success of the composting process and the usefulness of compost as an organic amendment are determined by microbial enzymes like cellulose, xylanase, manganese peroxidise, lignin peroxidise and laccase which are responsible for the breakdown of several organic compounds.

Table 1: Percentage of cellulose, hemicellulose and lignin in various types of lignocellulosic wastes

Lignocellulosic waste	Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)
Barley straw	33.8	21.9	13.8
Corn cobs	33.7	31.9	6.1
Corn stalks	35.0	16.8	7.0
Cotton stalks	58.5	14.4	21.5
Oat straw	39.4	27.1	17.5
Rice straw	36.2	19.0	9.9
Rye straw	37.6	30.5	19.0
Soya stalks	34.5	24.8	19.8
Sugarcane bagasse	40.0	27.0	10.0
Sunflower stalks	42.1	29.7	13.4
Wheat straw	32.9	24.0	8.9

Although, the microbial community naturally present in wastes usually carries out the process satisfactorily, the inoculation of residues with lignocellulolytic microorganisms is a strategy that could potentially enhance the organic substrate, bulking agents and the amendments used in composting are mostly derived from plant material.

Composting of agricultural residues through the action of lignocellulolytic microorganisms is easier to manage and it recycles the lignocellulosic waste with high economic efficiency. Lignocellulose, the composite of the predominant polymers of vascular plant biomass, is composed of polysaccharides like cellulose and hemicelluloses and the phenolic polymer lignin. Hence, the capacity of microorganisms to assimilate organic matter depends on their ability to produce the enzymes needed for degradation of the substrate components i.e., cellulose, hemicellulose and lignin. The more complex the substrate, the more extensive and comprehensive is the enzyme system required. Through the synergistic action of microorganisms, complex organic compounds are degraded to smaller molecules, which can then be utilized by microbial cells (Golueke, 1991).

MATERIALS AND METHODS

A. Source of agricultural waste (paddy straw): After harvesting of paddy crop the plant debris remains behind that is good source of substrates used for experiment. Paddy straw was collected from local supplier, Ghatkopar (Mumbai).

B. Source of fungal bioinoculants: The 4 different fungal strains were used for the composting process. The fungal strain such as *Aspergillus niger, Trichoderma harzianum* and *Chaetomium globosum* were procured from Agharkar Research Institue (NFCCI), Pune and *Pleurotus sajor-caju* was obtained from Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

C. Culturing of fungal strains: All the four fungal strains were inoculated on PDA (Potato Dextrose Agar and Potato Dextrose Broth) plates and slants, kept in incubator at 26^0C after inoculation. After sufficient growth, all cultures were used for further composting of substrates (paddy straw).

D. Experimental set up: 15 plastic drums were prepared for experiment. 15 kg paddy straw was collected, finally chopped into small pieces and were pasteurized by dipping it overnight in 0.1% formalin. (Each drum contains 1 kg substrates).

E. Composting of paddy straw with fungal inoculants: Paddy straw substrate was inoculated with fungal strains in various combinations for composting process. Pure cultures of *Pleurotus sajor-caju, Trichoderma harzianum, Aspergillus niger, Chaetomium globosum* (1gm of mycelium of each fungal strain per 1kg substrate) were inoculated in different combinations as given experimental set up. All 15 experimental drums were divided into 5 categories such as

For Paddy Straw:
(Each category done in triplicates)
Category 1: Control (Only paddy straw) (P)
Category 2*:* Paddy straw + *Pleurotus sajor-caju* (P+*P.s*)
Category 3: Paddy straw + *Pleurotus sajor-caju +Trichoderma harzianum* (P+*P.s+T.h*)
Category 4: Paddy straw+ *Pleurotus sajor-caju + Trichoderma harzianum+Aspergillus niger* (P+*P.s+T.h+A.n*)
Category 5: Paddy straw + *Pleurotus sajor-caju + Trichoderma harzianum + Aspergillus niger + Chaetomium globossum* (P+*P.s+T.h+A.n+C.g*)

F. Factors controlling composting process: The moisture was maintained around 60-80% through the experiment. Temperature also maintained. Turning/Aeration was done manually after every 4 days.

G. Chemical analysis: Analysis of Cellulose done by Anthrone method, Hemicellulose and Lignin by Reflux method (Sadasivam and Manickam, 2005).

Fig.1: Fungal bioinoculants pure cultures from authentic Research Institutes

Fig. 2: Controlling temperature in control (Paddy straw) experimental set up

Figure 3: Composted sample of treated paddy straw after 40 days
(From left to right control P+P.s, P+P.s+T.h, P+P.s+T.h+A.n, P+P.s+T.h+A.n, P+P.s+T.h+A.n+C.g)

RESULTS

Initial paddy straw contains (Table 2) cellulose 31.10%, hemicelluloses 15% and lignin 14.30%. Paddy straw was rich source of lingo-cellulose which was beneficial for fungal growth. Paddy straw was highly lingo-cellulosic waste. The result clearly showed that (Figure 4) there was significant difference in cellulose, hemicellulose and lignin percentage after composting with fungal bioinoculants in different combinations. Cellulose percentage in control (only paddy straw) was 23.5%, and it was further decreased like 21.2% (P+*P.s*), 17.4% (P+*P.s+T.h*), 15.95% (P+*P.s+T.h+A.n*), 13.38% (P + *P.s* + *T.h* + *A.n* + *C.g*).

Table 2: Composition of initial paddy straw

Sr. NO.	PARAMETERS	VALUES IN PERCENTAGE
1	Cellulose	31.10
2	Hemicellulose	15.00
3	Lignin	14.30

Table 3: Composition of Paddy straw after composting with fungal bioinoculants for 40 days

PARAMETERS	Control(P)	P+ P.s	P+P.s+T.h	P+P.s+T.h+An	P+P.s+T.h+A.n+Cg
Cellulose	23.5±0.5	21.2±0.1	17.4±0.3	15.95±0.55	13.38±0.71
Hemicellulose	13.9±0.1	13.16±0.64	12.1±0	11.7±0.1	7.4±1.9
Lignin	12.7±1.20	8.65±0.45	7.85±0.15	7.3±0.3	3.35±1.15

Note: All values are mean and standard deviation of three replicates (M± SD).

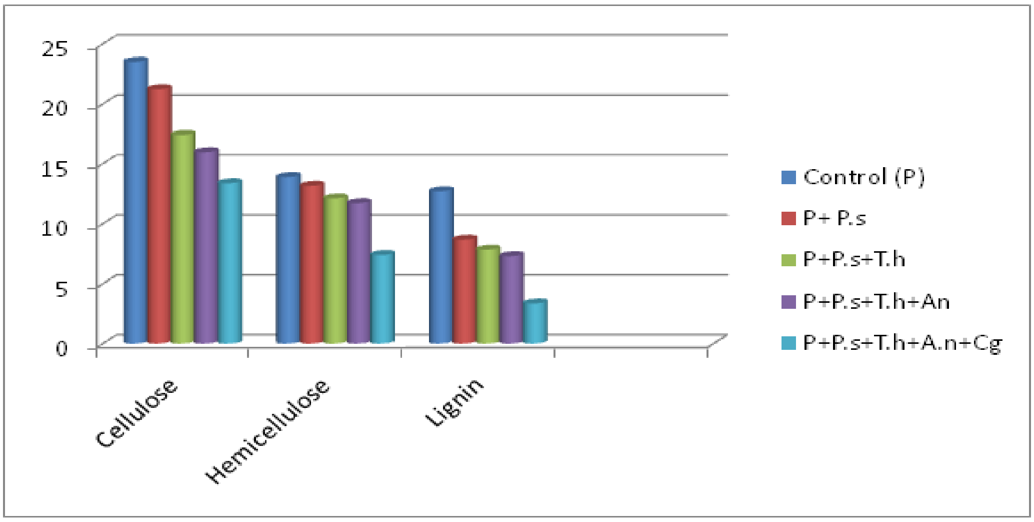

Figure 4: Comparision of cellulose, hemicellulose and lignin in different treated set up after 40 days of composting

Hemicellulose percentage in control was 13.9%, and it was further decreased like 13.16% (P+P.s), 12.1% (P+P.s+T.h), 11.7% (P+P.s+T.h+A.n) and 7.4% (P+P.s+T.h+A.n+C.g). Lignin showed 12.7% in control followed by 8.65%, 7.85%, 7.3% and 3.35% respectively as above. Dubey and Maheshwan (2005) have stated that the cellulytic fungi, such as *Aspergillus, Trichoderma, penicillium and Trichurus* accelerate composting for efficient recycling of dry crop wastes with high C:N ratio and reduce the composting period for about one month. *P. sajor-caju* has varying enzyme activities (Buswell and Chang, 1994). *Trichoderma* and *Aspergillus* degrade hemicelluloses and cellulose respectively, if these microfloras were added during pre-decomposition of the waste, the time of composting might be reduced (Singh and Sharma, 2002). Fungi are also used for remediation process, *Trichoderma virdie* proved as a good remediasing agent compared with other micro-organismas, it degrades wastes without polluting environment. Several fungi like *Trichoderma harzianum, Pleurotus ostreatus, polyporus ostriformis and Phanerochaete chrysosporium* are known to play important role in composting of lignocellulosic materials (Singh *et al.*, 2012). *Chaetomium globosum*, which have ability to produce both ligninolytic and cellulolytic activity (Nagdesi and Arya, 2013). Zeng *et al.* (2010) showed the above higher activities of enzymes with *Phanerochaete chrysosporium* inoculation during agricultural waste composting. The microbial community already existed in the waste helping the composting process effectively, the inoculation of residues with ligno-cellulytic microorganisms is a another strategy that could potentially enhance the way the process takes place or the properties of the final product. Inoculation with bacteria and fungi which can breakdown lingo-cellulolytic material has been reported to be effective in composting (Nair and Okamitsu, 2010). DanLian *et al*. (2010) tested the microbial populations and their relationship to bioconversion of lingo-cellulosic wastes during composting.

CONCLUSION

From the lingo-cellulose waste degradation point of view, the results presented above suggests that this system would be the best for agricultural and other wastes which are rich source of lingo-cellulose content. An agricultural waste has great agronomic and economic potentials as well as sustaining the environment. This study suggests that bio-stabilization of agricultural wastes with the help of fungal inoculants could be potential technology to convert noxious wastes into nutrient rich bio-fertilizer. Finally, agricultural wastes could be utilized as an efficient soil conditioner for sustainable land practices after processing by composting with fungal inoculants. This method would enable us to potentially convert the waste into value added products in a short time.

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