A proposal on

A study on the collection/shredding of mixed agricultural waste biomass for optimized compost production

Technical Proposal
Submitted for

CSR

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Abstract

Title of Project:

A study on the collection/shredding of mixed agricultural waste biomass for optimized compost production

Introduction/Background:

In Indian farms it is generally observed that the cost of gathering and accumulating all the agricultural waste at a collection point itself is prohibitive for the farmers. This in general is a consequence of the small farm areas and reluctance of mechanization on Indian farms which is well reported in [1]. Among the various types of traditional agricultural material handling systems, the one which appears suitable for collection of waste from Indian farms is the readily adaptable tractor scoop (shovel) combined with a truck or tractor mounted cart, or simply a tractor trailer. Chipping, shredding and pulverization are the main mechanical operations done for converting macro agricultural waste products into small or micro easily decomposable form, which can be used as organic manure. These devices are often equipped with powerful blowers to direct the chips into an output chute. Over the past years, a lot of attention has been given to energy conversion techniques and renewable energy sources. A key source of renewable energy is Bioenergy and it plays a key role in mitigating climate change. A critical factor to realize full potential of Bioenergy is the management of the biomass supply chains, which include logistics design and coordination among stakeholders of the supply chain leading to sustainable supply chains.

Objectives of the project:

This study is aimed at outlining the technology solutions and supply-chain management issues in compost production from agricultural biomass.

Expected Outcome:

Our contribution to this project would be selection of suitable microbial cultures suitable for each type of waste and blend of materials suitable for microbial composting to bio-fertilizers and process for biodegradable packaging material.

Target population/ Beneficiary:

The study will focus on the following key areas in Karur district of Tamilnadu

Time Line and Budget:

The estimated budget for this project is Rs. 27.50 lakhs for the period of 18 months.

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Topic

A study on the collection/shredding of mixed agricultural waste biomass for optimized compost production

Objectives

This study is aimed at outlining the technology solutions and supply-chain management issues in compost production from agricultural biomass. The study will focus on the following key areas in Karur district of Tamilnadu:

1. Collection and shredding of biomass
2. Supply-chain of waste to compost
3. Optimized production of compost

These objectives are based on the preliminary work carried out as part of internship programme of Rural Technology Action Group (RUTAG), IIT Madras in Karur. During the internship, problem formulation, and trial implementation was done in coordination with a local farmers and an NGO Pothu Vivasayeegal Sangam. The initiation of internship was due to the efforts of Mr. T N Sivasubramaniam, Karur associated with the NGO. The background based on this study, and wider literature is provided in the next section.

Literature review and background

The large amounts of unused or underused biomass resources, such as agricultural and forestry residues, industrial and municipal organic waste, may serve as raw material for the preparation of compost, specially designed for the need of a particular crop. The worldwide need to restore the productivity and humus forming ability of infertile or overburdened soils requires the application of special soil inoculants, organic composts and / or fertilizers.

The main type of agricultural wastes envisaged in Karur District are related to sugarcane, banana, korai grass, tapioca and paddy and miscellanoues wastes such as twigs and dry leaves. Thereafter from the mechanical operations point of view, there are two challenges typically faced by farmers in the agricultural waste processing. The first is the collection of material from various farms and the other is the next step of shredding/chipping/pulverisization of the waste products.

Collection and shredding of biomass

In Indian farms it is generally observed that the cost of gathering and accumulating all the agricultural waste at a collection point itself is prohibitive for the farmers. This in general is a consequence of the small farm areas and reluctance of mechanization on Indian farms which is well reported in [1]. Among the various types of traditional agricultural material handling systems, the one which appears suitable for collection of waste from Indian farms is the readily adaptible tractor scoop (shovel) combined with a truck or tractor mounted cart, or simply a tractor trailer [2].

Chipping, shredding and pulverization are the main mechanical operations done for converting macro agricultural waste products into small or micro easily decomposable form, which can be used as organic manure. The main differences between these products are the sizes of the processed wastes [3-

4]. In chipper machines, input materials are cut into moderately sized pieces of length above 10mm. There is a rotating set of sharp blades mounted on a heavy disk and a stationary blade. The waste material is sheared or cut in between the stationary and rotating blades into chips. There are also drum type of chipper blades. The output chip size depends on input material cross section, and hardness, and also the feed rate and RPM of the rotating blade [5]. Shredder machines have multiple blunt shredding blades which act as more as hammers to beat and shred the materials into very small particles from 5 to 10 mm in size. Shredding requires more energy than chipping. Pulverizing is a method of grinding waste into small powder form, using either blunt hammers or being crushed between rollers. These devices are often equipped with powerful blowers to direct the chips into an output chute. The power requirements of these devices vary with the size of input material ; for example for tree branches upto 50mm in diameter and a productivity of 500kg/hr needs 10hp engine. For tree branches up to 100mm diameter, the power requirement is 20-30hp. The cutting power and blower power required generally increases for wet waste material. The cutting power has a complicated relationship with moisture, the power requirement decreases with moderate moisture, then increases. There are also many variations of size and portability of chipping/shredding machines[6-7]. The portable ones are usually in the 10-18 hp range and can be towed to a field and work from the PTO shaft of a tractor. The larger ones are permanently installed and driven by dedicated diesel engines or heavy motors.

The status of development of these devices in India is as follows. A number of companies such as Sree Jayamurugan Agro Links, Kovai Engineering etc in Tamilnadu produce models of chipper/shredders in a wide range of sizes. These range from small 10HP electrically operated portable shredder suitable for agricultural waste like dried leaves, small branches of trees (up to 75 mm Diameter), mulberry stem, coconut fronds, harvested banana trees and papaya trees etc at a cost of Rs 1 lakh, to a large 45HP unit driven by external tractor PTO shaft capable of both shredding and pulverizing agricultural waste like coconut fronds, tree branches (up to 100 mm Diameter), banana, papaya, areca nut trees etc., at a cost of Rs 1.5 lakhs. The feedback from some of the farmers in Karur (through the NGO Pothu Vivasayeegal Sangam) who use these machines is that the size of shredding is not consistent and rather large to be effective in composting. These are more used as general mechanical shredders to reduce the volume of the waste and then to be disposed. Moreover there is no automatic feeder, or positive feeding into the chipping machines. The agricultural waste has to be manually fed at perhaps efficiency by different workers. A number of research articles in Indian journals, and project reports from Farm Machinery Departments in Agricultural Universities in India have highlighted the efforts made to reduce the cost of shredding machinery and to improve the efficiency, but there no follow ups reported in these cases. For example in [8] an effort is made to study various cutters for most efficient shredding of cotton stalks and the resulting optimal cutter lead to a 37% saving in cost of operations and in [9] an effort is made to synthesize a portable machine with a two stage process of first cutting and then pulverizing light farm waste loads such as areca, coconut leaves and grasses using hammer-like blades. The various shredders and chipping machines do not appear to give usable chip sizes for different types of waste.

Supply-chain of waste to compost

Over the past years, a lot of attention has been given to energy conversion techniques and renewable energy sources. A key source of renewable energy is Bioenergy and it plays a key role in mitigating climate change. A critical factor to realize full potential of Bioenergy is the management of the biomass supply chains, which include logistics design and coordination among stakeholders of the supply chain leading to sustainable supply chains.

Biomass supply chains are different from traditional supply chains. One of the key challenges is that Agri-biomass supply chains are characterized by seasonal availability, perishable nature of the biomass, uncertain lead times in transportation, large degree of uncertainty about the quality and quantity of biomass etc. These challenges necessitate a need to develop good inventory policies for storing biomass over a time horizon. The specific challenges coupled with inefficiencies along the supply chains due to fragmented nature and unorganized players lead to poor prices for the farmers and high prices at a consumer end. The economic dimension of supply chains examines the economic condition of stakeholders along with logistics and distribution costs along the supply chains. The burning of crops and nature of biomass leads to many environmental challenges and contribute towards the environmental dimension of supply chains. Exploration of the social effects of biomass production, especially termed as waste-to-wealth, and the social impact of bioenergy facilities on local communities add to the social dimension of sustainability.

Optimized production of compost

For composting, special microbial starter cultures are prepared by anaerobic or aerobic submerged fermentation of 6–8 different microorganisms /bacteria including Actinomycetes/. The microbes are grown to 109–1010CFU/ml and mixed in the appropriate proportion to suit the composting process, directed to a particular plant residue like straw , bagasse ,coir pith etc . About 5–10% v/v of the mixed microbial culture is added to the selected organic carrier, and composted anaerobically or aerobically at a determined optimal temperature, pH, pO2, C:N ratio for 25–60 days. In such a directed compost the desired added microbes are the predominant species. Directed composts are prepared for field crops, vegetables, agricultural and forestry residues etc by adding a sequence of microbial cultures to cater to the different stages of composting. Such composts are now marketed as commercial products. As the plant cell walls contain lignin, addition of lignolytic microbes can first break down the tight complex between lignin and the other components and release the other fibers like cellulose and hemicellulose . Examples of lignolytic fungi are Phanaerochaete .Once cellulose is released this can be attacked by cellulolytic organisms like Trichoderma harzianum whch hydrolyses it to sugars .These sugars can be utilized by nitrogen fixing bacteria and other sachharolytic organisms which enrich the material with nitrogen, Hence in the process the plant residues are converted to bio fertilizers rich in nitrogen .The C/N ratios which can be as high as 50 to 75 in the agro residue like paddy straw can be brought down to the C/N ratios of 10-15 desirable for a bio-fertilizer.

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Methodology

Study area of this study will be Karur district of Tamilnadu. Investigators will work closely with the NGO Pothu Vivasayeegal Sangam based in Karur district for implementation of the study. The summer internship experience and current local practices will be used as initiating points. The salient features of the summer study carried under RUTAG IIT Madras are given below:

- standardized a procedure for a speedy process of conversion of agro-waste into valuable compost using easily available ingredients from the farmers' own fields.
- focused on different types of wastes, their collection and shredding
- the standardized procedure resulted in a short term process of compost production within 7-9 weeks.
- farmers club can also adopt enterprises of the compost with enriched microbes through packaging and marketing.
- The cost of the project for trial of 30 kg batch size was also modest, and the overall process was designed with special emphasis on being portable. The overall promised goals of simplicity, low cost, portability and utility were achieved.
- Coordination and guidance from Mr. T N Sivasubramaniam, Karur throughout the project was crucial in carrying out initial scoping and trials

Based on this experience, the study will focus on 3 different stages of the project:

1. Collection and shredding of biomass

The tractor scoop with hydraulic arms can be readily fitted to a 60hp tractor. A tiltable trailer can unload the waste quickly at the collection point. The more complicated farm material handling devices such as conveyors, bucket lifts etc. are of a permanent fitting. Further studies into these aspects are necessary with interaction from farmers and NGO’s before arriving an optimum suggestion.

This study envisages consideration of the following agricultural waste residues:

i. Coconut trees
ii. Banana
iii. Tapioca
iv. Millets
v. Sugarcane
vi. Korai grass
vii. Paddy
viii. Prosopis Juliflora

Conceptual designs of mechanical shredders and chipping machines that can yield usable chip sizes for different types of waste will be developed. During the study, a few trials with quick-simple modifications of existing machines may be attempted. Similarly, CAD and analysis of ideated machines may be undertaken to confirm the proof of concept.

2. Supply-chain of waste to compost

The project would explore the critical issues for all stakeholders of the supply chain. In particular, the questions would focus on the following issues

i. From a supply chain perspective, what are the strategic, tactical and operational decisions for developing biomass supply chains. The strategic decisions would involve policy making while the aggregate production planning, harvesting, transportation planning, storage methods would contribute towards tactical and operational decisions.
ii. What are the drivers across the three dimensions of sustainability: economic, environment and social dimension?

We will employ a case-study based approach to evaluate the various flows in the biomass supply chains across the three dimensions of sustainability. This approach would include listing various logistics, financial, social, inventory, and distribution challenges faced by the supply chain and examine environmental sustainability and social responsibility issues.

3. Optimized production of compost

Although the above biodegradation of the lignin and cell wall components can occur naturally also they are time consuming and generally take over 60 days to bring down the C/N ratios even under the best of conditions . Accelerated composting with aid of suitable composting cultures judiciously added can make the process rapid and compost within 45 days .Some of these processes were proven in our previous work on degradation of sugar cane trash, with press mud in the Indo-Swiss DBT Project on composting .

Another development in the area of composting recently, is to develop mechanized composting wherein with a systemized auto controlled method of aeration , temperature , and turning of the compost (stirring in bioreactors) the composting process can be made to occur very rapidly within 15 days The major advantages of these method is that the land area is reduced, the turnover of composting is not more than 15 days allowing more residues to be recycled quickly , there is no fouling by flies/ insects or health hazards of exposed mould growths, and process is not affected by the climate conditions and wash-out by rains . Considering these several advantages there is current trends to develop such “BIOCOMPOSTERS” and install suitably. These systems have to be optimized with addition of microbial cultures suited for the high aeration thermophilic composting.

A recent development in connection with composting of paddy straw and fibrous material is to compost material to let the partially grown fungal mycelial to overgrow on the material and bind together the particles of the residues. This partially grown fungal biomass material on subjecting to suitable high pressure and temperature can be compacted to give a light weight hard board which can stand impact and can be used as a “BIODEGRADABLE PACKAGING MATERIAL“. Such boards are biodegradable without needing any binder, and can replace the deadly polystyrene and other synthetic packaging materials that do not degrade for even over 500 years and are polluting the earth.

Relevance of the study

Sustainability in a supply chain occurs when the supply chain members consider and balance the goals relating to economic, environmental and social dimensions. Economic dimension looks at the profitability of the supply chain members; environmental dimension looks at the sustainability of the natural environment; and social dimension looks at the human capital. These three dimensions are collectively referred to as the triple bottom line approach. Sustainability of the supply chain necessitates sustainability for all stakeholders in the supply chain; and the sustainability of all the stakeholders implies sustainability of the supply chain.

Thus an overall review into the use of mechanical processing of agricultural waste in India with emphasis on Karur, and also based on feedback from NGO Pothu Vivasayeegal Sangam suggests that although the technology is available in the market in some form, it is not correctly directed at the need for composting. So, this study envisages enlisting of mechanical technology solutions to the problems of collection and shredding of mixed agricultural waste.

Our contribution to this project would be selection of suitable microbial cultures suitable for each type of waste and blend of materials suitable for microbial composting to bio-fertilizers and process for biodegradable packaging material.

Given that this study will focus on 3 interdependent areas, with close coordination with Mr. TN Sivasubramaniam and Pothu Vivasayeegal Sangam, the deliverables of technology and management solutions are expected to be immediately implementable in near future.

Proposed report

The final report will consist of the following sections (study area: Karur district, Tamilnadu):

1. Survey of curent practices of agricultural waste handling
2. Proposed technology solutions for collection/shredding
3. Supply-chain management of waste to compost
4. Optimized compost production designs
5. Overall recommendations
    a) Technology and management solutions implentable in Karur and similar areas of Tamilnadu
    b) Applicability of technology and management solutions to broader situations
    c) Key technological problems to be solved

Work plan

S. No.	Items	Duration (18 months)
1	Selection of staff	1st month
2	Preliminary scoping, pilot visit	2nd - 4th month
3	Case-studies, data collection, survey a) Type/amount of agricultural waste b) Existing supply-chain c) Current practices	3rd - 9th month
4	Case-studies, data collection, survey, preliminary solutions a) Collection scenario building, mechanical device ideation b) Shredding mechanisms, and machine conceptualization c) Optimum designs of enzyme systems d) Best practices for composting production e) Supply – chain management	6th - 15th month
5	Draft report preparation a) Consolidation of data, findings, learnings b) Modifications to conceptual technology solutions c) Firming up of cost/benefit analysis	15th - 17th month
6	Final report preparation	18th month

Proposed budget

S. No.	Item	Amount (in Rs lakhs)
1	Project staff, Research staff (4) Field staff (2-4)	10
2	Travel and DA	4
3	Consummables and contigencies	5
4	Preliminary prototyping, laboratory testing, field trials	6
Sub-total		25
Overheads (10%)		2.5
Total		27.5