Guidelines on Pellet Production from Co-compost with Fecal Sludge

International Water Management Institute

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List of Abbreviations

CEA	Central Environmental Authority
C	Carbon
DFS	Dried Fecal Sludge
FS	Fecal Sludge
IWMI	International Water Management Institute
MSW	Municipal Solid Waste
N	Nitrogen
RF	Rice Flour
SA	Surface Area
SLS	Sri Lanka Standards
V	Volume
WHO	World Health Organization

1. Introduction

Co-composting is considered a suitable, low cost, waste treatment option for developing countries that allows recycling of organic waste from various waste streams in a combined manner (IWMI, 2016) while providing a sustainable solution for multiple waste streams. Co-composting adds value to the final product by complementing the individual benefits from each raw material if the input materials are carefully selected. Solid waste and fecal sludge (FS) are two major urban waste pollution streams in Sri Lanka that needs urgent attention towards proper management. Organic fraction of the solid waste and FS complement to each other during co-composting process with the reasons tabled below and consequently provide one total solution for the two urban waste streams;

Table 1 – Sludge and organic solid waste complementary reasons

Sludge	MSW
High in nutrients	Low in nutrients. High in carbon
High in moisture	Low in moisture
Fine particles	Larger particles and can act as bulking agent
May be degraded and cannot achieve high temperatures to obtain final sanitized product*	Fresh waste can achieve high temperatures

*During the composting process pathogens are inactivated due to the high temperatures achieved, hence the final product is safe to use as a soil conditioner-cum-fertilizer.

Pelletization on the other hand is a process that is intended for enhancing the market value of compost by addressing the drawbacks of compost usage. Compost is bulk in nature and thus not easy and/or costly to package, store, transport, handling and application. Apart from that, compost handling often generates dust at the point of application which can cause health and sanitation risks to the farmers. Through pelletization the density of the product is increased and as a result of the compact nature, the product is easy to handle and transport which consequently increases the marketability of the compost.

Co-composting combined with pelletizing shows promising evidences on value addition of the compost product that ensures the sustainability of the entire process. This report provides guidelines for co-composting and pelletization that will be helpful for practitioners, planners, and other implementation agencies in order to develop and implement related activities.

2. Co-composting

Composting refers to the process by which biodegradable waste is biologically decomposed under controlled conditions by microorganisms under aerobic and thermophilic conditions. *Co-composting* means the composting of two or more raw materials together – in this case, FS and organic waste. Organic materials, which can be used for co-composting comprises organic fraction of the municipal solid waste (MSW) (e.g. market waste, catering food waste), animal manure, sawdust, rice husk, wood chips, agricultural waste, slaughterhouse waste or solid residues from food and beverage industries.

Figure 1 illustrates the general material flow and main process components of co-composting.

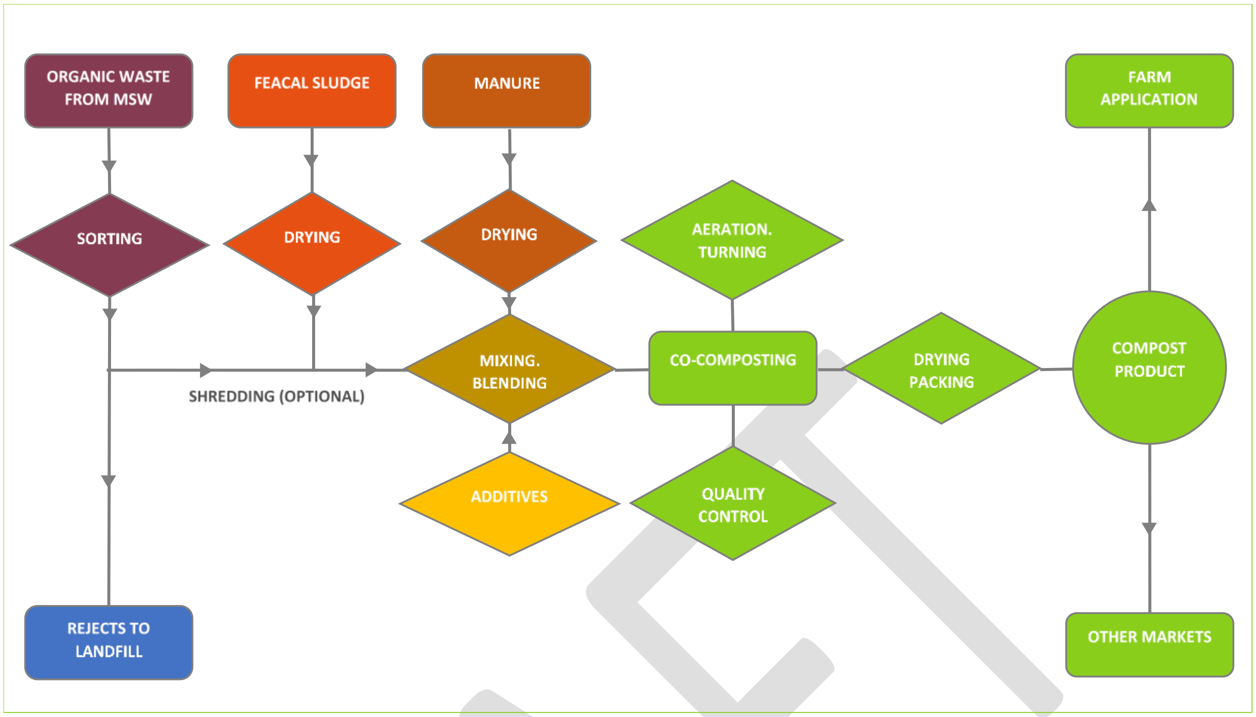


Figure 1: General material flow and main process components of co-composting (source: IWMI, 2016)

2.1. Raw materials

The quality of the compost depends on the quality of the input materials. Poorly feed stock yields poor quality finished compost. Thus it is of utmost importance to use the right feedstock materials in the right condition for the process.

Due to the compactness of FS and the high moisture content, in most cases the addition of a bulking agent is required to provide structural support in improving the aeration. The most commonly used bulking agents are fibrous carbonaceous materials with low moisture content such as cereal straw, husks, wood chippings, leaves, fruit pods, empty fruit bunches, saw dust and materials that usually have a C:N ratio in the range of 50: 1 to 80:1. The type and proportion of the bulking agent will influence the rate of decomposition, nutrient, carbon and water content and the final compost quality. The optimum Carbon: Nitrogen (C:N) ratio for composting is presented in Table 3 and appropriate volumetric ratios for bulking agents with dewatered sludge can be ranged from 1:1 to 3:1

In the selection of feedstock, both green (high in nitrogen) and brown (high in carbon and the bulking material falls into this category) organic waste should be considered in order to create optimum conditions for microbial activity during composting (table 2).

Table 2: Green waste and brown waste

Green waste	Brown waste
Fruits, vegetables, manure, fresh yard waste and kitchen scarps	Straw, rice husk, dry leaves. saw dust and other woody residues

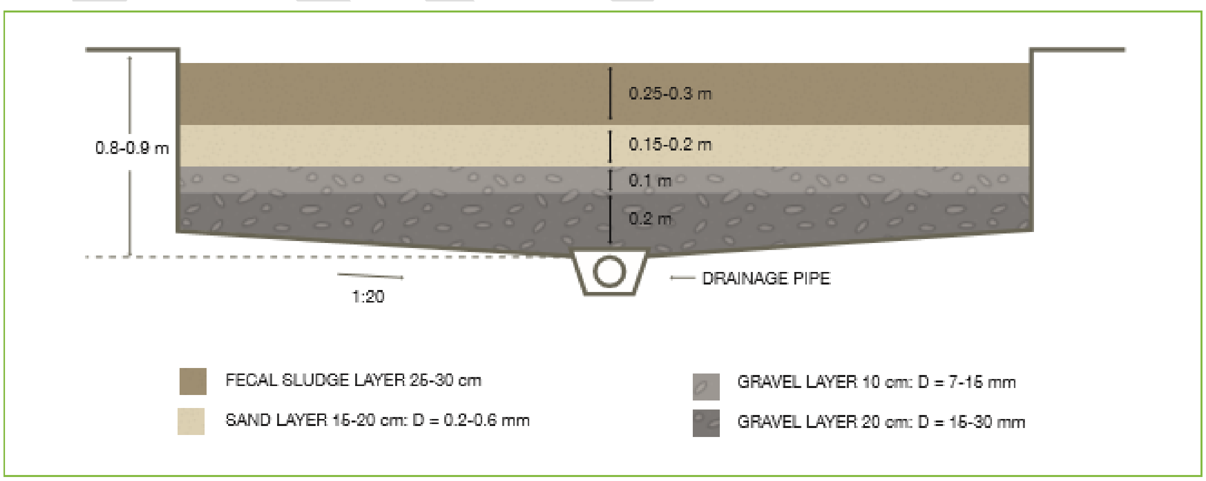
Most of the time raw materials need to be prepared before adding to the composting process. MSW is typically considered to be mixed and not commonly segregated into specific categories such as biodegradables, recyclables, inerts and so forth. However, with the recent attempts by the Sri Lankan Government on strictly regulating waste separation at source, the amount of waste collected in segregated manner are increasing. For composting process only organic portion of the MSW is utilized thus proper segregation needs to be taken place prior to composting. Moreover, input materials that contain potentially hazardous waste (e.g.: hospital waste), contaminated waste and waste with impurities should not be removed prior to composting.

2.2. Dewatering of FS

As a result of common wet based sanitation practices of Sri Lanka, FS collected from the onsite sanitation systems usually contains high moisture content. Dewatering of FS is therefore essential to achieve a suitable moisture content for composting. A variety of dewatering technologies are available that can be applied depending on the sludge characteristics and several other criteria such as cost, land requirement and other local contexts. The technologies ranges from natural systems such as unplanted drying beds to mechanical systems such as filter press and centrifuges. Belt filter press is among the most common technologies for dewatering of sewage sludge whereas unplanted drying beds are commonly used for dewatering of FS.

IWMI publication Resource Recovery and Reuse series 2 on Technological options for safe resource recovery from FS provides more information in the options for dewatering technologies. Being the most common dewatering technology, unplanted drying bed is discussed in details in this report.

Unplanted drying beds facilitates dewatering through percolation and evaporation (mostly via percolation). In drying beds sand and gravel act as the media on which, batch loads of septage are fed and subsequently dewatered. Essentially, three layers of media with different sizes of graded sand and gravel are laid for effective percolation. Figure 2 illustrates a typical cross section of a drying and filtration bed. Typically, sludge is sun dried for about 14 to 21 days, however drying period may vary according to the weather conditions in the area.



Source: Cofie et al. 2006

Figure 2: Profile of an unplanted drying bed

Upon required drying conditions FS can be manually removed from the drying beds and piled up as necessary for co-composting.

Figure 3: FS in a drying bed after 10-12days

Figure 4: FS in a drying bed after 15-20days

Figure 5: Manual Collection of dried fecal sludge

Figure 6: Piling up of DFS

2.3. Co-composting Process

The two main types of composting systems are generally distinguished 1) open systems such as windrows and static piles and 2) closed 'in-vessel' systems. In-vessel systems require higher investment compared to static systems and are more expensive to operate and maintain. Hence open systems are considered to be the preferred option for composting in low income counties and well suited for topical countries. Under the Pilisaru National Solid Waste Management Programme implemented by Central Environmental Authority (CEA), more than 115 compost plants have been established in several local authorities in the country. Incorporating sludge component into the existing composting practices will assist in terms of not only value addition but also managing multiple waste streams in an integrated manner with minimal capital investment and reduced operational inputs. This could demonstrate an attractive model of integrated waste management at the local level.

2.3.1. Construction of Windrows

The best sized particles for composting are less than 2 inches (or 50 mm) in the largest dimension. In order to reduce the particle size, organic waste can be shredded and the dried FS can be pulverized as necessary. Shredding exposes a greater surface area, which makes it more susceptible to bacterial activities or biodegradation. Large pieces of wood or leaves do not decompose quickly in a compost pile. Insufficient oxygen in the center does not permit more rapid aerobic decomposition.

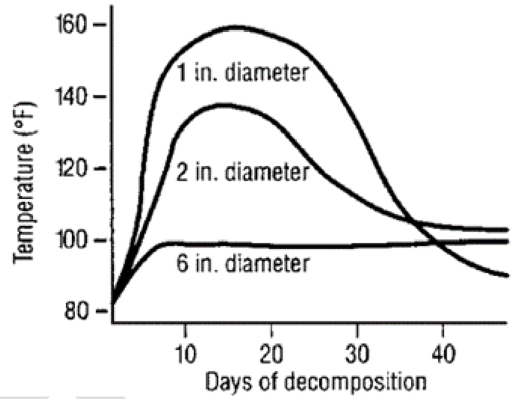


Figure 7: Particle size effects on composting

Sorted out organic waste and dried FS are heaped in layers to construct the windrows. Dried FS and organic waste have to be weighted and the right amounts should be mixed as per the required mixing proportions. While constructing, piles are watered to maintain the required moisture content. Size of the piles must be sufficient to maintain the proper temperature along with required oxygenation. However, it is of importance to minimize the surface area to volume (SA/V) ratio of compost piles to increase the efficiency of the composting process (Malwana et al, 2013).

Figure 8: Construction of Windrows

2.3.2. Turning of windrows

Excessively high temperatures and insufficient oxygen levels are two key factors that inhibits the decomposing process of compost piles. Turning plays an important role in maintaining optimum temperature and creating more air pockets in the composting mass that subsequently improves the activities of aerobic microbes. Turning of a windrow is essentially decided based on the windrow temperature than adhering to a fixed turning interval. During the initial stage of composting, high temperatures generated within the pile demand frequent turning and later in the process reduced temperatures demand low frequency of turning. Figure 6 depicts the sequence that need to be followed while turning a compost pile in order to ensure the proper heat distribution and air circulation of across a compost pile.

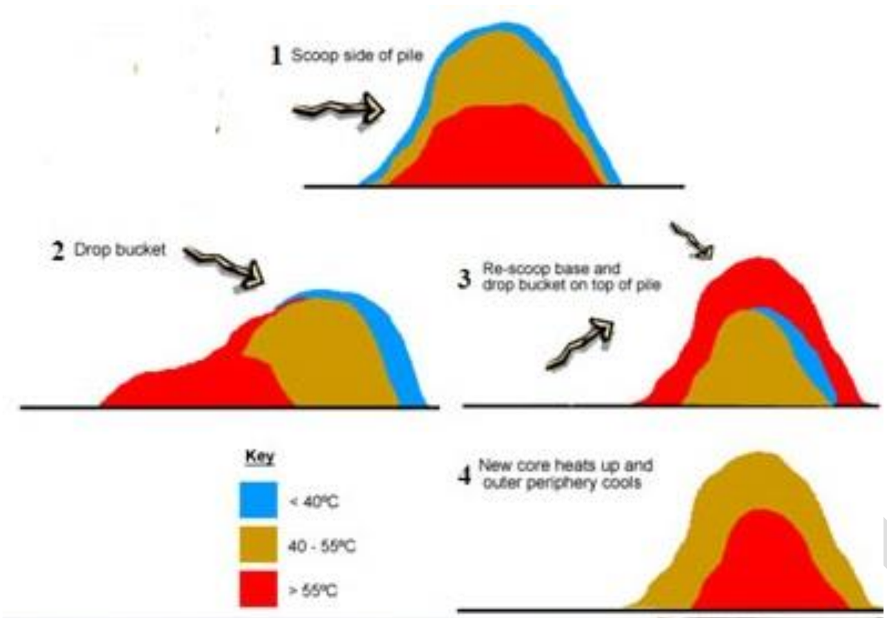


Figure 9: Turning sequence of a compost pile

2.3.3. Optimum condition for composting

The key parameters affecting the biological decomposition processes are listed in the table 3 below.

Table 3: Key parameter governing the composting process

Major Parameter	Optimum range	Impacts of the deviations from the optimum
C:N ratio	25:1 - 30:1*	High C:N – low nutrient, slow process Low C:N –rapid process, nitrogen loss as ammonia
Moisture Content	40-65%	Low – slow process High – anaerobic condition
Temperature	50- 70°C	Low – Slow process (loose thermophlic process) High – Loss of microorganisms
Pile size	36" x 36" x 36" (minimum)	Depend on material and climatic conditions. If too large anaerobic conditions occur near center and if too small heat loss
Particle size of the feedstock	0.5"– 1.5" *	Low – low air supply High – longer process time
Air supply	Oxygen supply via turning	Low oxygen supply leads anaerobic conditions

Apart from maintaining the aforementioned optimum conditions for composting process, labelling each compost pile and maintaining good housekeeping standards such as keeping the composting platform clean and tidy are recommended as good composting practices to be followed for sustainable composting practices.

2.3.4. Curing phase

When the microbial activity decreases gradually and there is no temperature rise in the compost pile, active phase of the composting process diminishes and the curing phase of the compost starts. Parent feedstock quality, the manner and the degree of stability of the decomposing organic matter will influence the time required for curing to stabilize the compost. A germination test can be conducted to ensure the co-compost is mature. Past studies confirm that the germination bioassay using lettuce seed was sensitive enough and able to identify the presence of phytotoxic compounds in compost. Upon the completion of curing phase, compost can be sieved manually or mechanically depending on the availability of resources.

Figure 10: Manual Sieving

Figure 11: Mechanical sieving

2.4. Quality of Co-compost

Quality is an important factor when compost is sold as a commercial product. Compost quality standards should be stringent and enforced to protect public health and safety, and to increase confidence and demand among farmers. Sri Lanka has published specifications for compost from MSW and agricultural waste prescribing the requirements to comply with (table 4). However, these standards should be revisited to match the possible variations of the quality of the final product from the co-composting with FS component, specifically by adding biological indicator acceptable ranges, which are shown in Table 5.

Table 4: Requirements for compost products (Sri Lanka standard 1246:2003)

Category of requirements	Evaluation item	Acceptable Range	Method of test
Physical Requirements	1) Colour	Brown/ grey to dark black	
	2) Keeping properties	within 12 months from date of production	
	3) Moisture content	Less than 25% moisture by dry mass	

	4) Odour	no unpleasant odour	
	5) Particle size	Residue of not more than 2% by mass	
	6) Sand content	Not more than 10% sand contained	
Nutrient Requirements	1) pH	6.5 - 8.5	ISO 10390
	2) Organic carbon	20%	Walkley - Blak Method
	3) Nitrogen	1.0%	SLS 645: Part 1
	4) Phosphorus (P_2O_2)	0.5%	SLS 645: Part 5
	5) Potassium (K_2O)	1.0%	SLS 645: Part 4 Section 1
	6) Magnesium (Mg)	0.5%	SLS 645: Part 6
	7) Calcium (Ca)	0.7%	SLS 645: Part 6
Nutrient Requirements	1) Cadmium	10 ppm max	ISO 10390
	2) Chromium	1000 ppm max	Walkley - Blak Method
	3) Copper	400 ppm max	SLS 645: Part 1
	4) Lead	250 ppm max	SLS 645: Part 5
	5) Mercury	02 ppm max	SLS 645: Part 4 Section 1
	6) Nickel	100 ppm max	SLS 645: Part 6
	7) Zinc	1000 ppm max	SLS 645: Part 6
Biological requirements		Should not contain more than 16 viable need seed per 1 msq	
Micro biological requirements	1) Faecal coliforms per g	Free	SLS 516: Part 3
	2) Salmonella per 25g	Free	SLS 516: Part 5

Source: Sri Lanka Standard Institution, 2003

Table 5 – Additional biological parameters for human excreta reuse in agriculture from WHO (2006) standard

	Helminth eggs (number per gram total solid)	**E. coli (number per gram total solid)**
Treated faeces and faecal sludge	< 1/g total solids	<1000 g/total solids

WHO guidelines recommends that the temperature above 50ºC should be obtained in the compost piles for at least one week to ensure a safe product (WHO, 2006).

3. Pelletization

Compost is bulky in nature and marketed in loose form. This creates many practical difficulties related to packaging, storing, transporting, handling, and application (farm level). Alternatively, compost handling often generates dust at the point of application, which may cause health and sanitation risks for farmers (Hara, 2011; Zafari and Kianmehr, 2012).

Pelletization can be applied as a solution to the aforementioned drawbacks of compost. Pelletization is the use of mechanical pressure to increase the material density while converting it into pellets. Typically, compost pellets are in cylindrical shape, 5–10 mm in diameter, and 25– 30 mm in length. This uniform size, shape, and other physical properties make it more convenient for storage and application (Hara, 2001). Consequently, pellets require 20–50% less packaging volume than powdered composts with a final specific gravity over 1000 kg/m3 (Carter, 2010). Pelletization can contribute in enhancing the market value of the product.

3.1. Pelletization Process

Pelletizing process consists of several steps as displayed in Figure 2. Matured compost (Co-compost) is first sieved with a recommended sized mesh and then mixed with binding agents, enrichment agents (optional), and water. Afterwards, the prepared mixture is used as input material for the pelletizer (Figure??) and pellets are produced. Produced pellets are then sieved and dried prior to packing and storing.

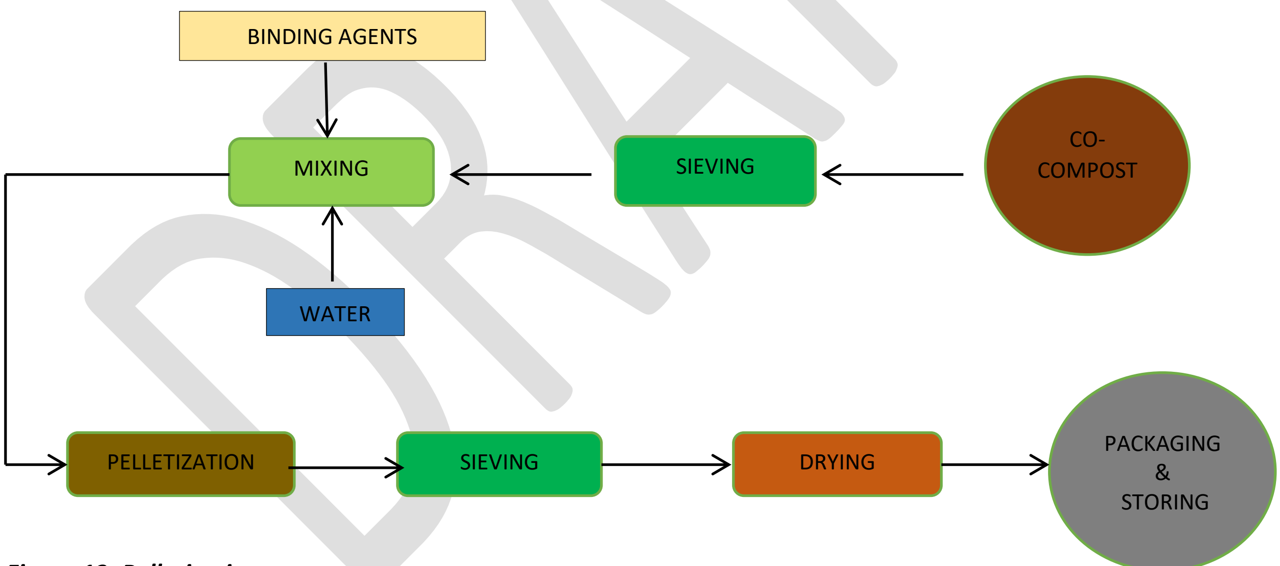


Figure 12: Pelletization process

3.1.1. Moisture addition

Moisture content of the final co-compost product is generally within the range of 20-25%. According to the initial tests, appropriate minimum moisture content for pelletization is about 25%. Therefore, moisture content of the compost mixtures should be adjusted to 25% by adding water as required. The moisture content of the compost can be measured with a portable moisture meter as shown in Figure 7.

Pelletizing Machine (Specifications etc)

Figure13: Monitoring the moisture content of co-compost

3.1.2. Mixing with additives

For the effective pelletization process, binding agent can be added (optional) to the compost mixture to enhance the binding properties of the pellets. A locally available material such as waste Rice Flour (RF) can be used as a binding agent at a suitable concentration. After the addition, binding agent should be mixed thoroughly with the co-compost (Figures 8).

Figure 14: Adding additives;

Figure 15: Mixing of co-compost

Note:

Depending on the requirement, a nutrient-enriching agent can be incorporated to enhance nutrient value of co-compost. For example, adding Ammonium Sulphate [AS; $(NH_4)_2SO_4$)] can enhance Nitrogen (N).

3.1.3. Pelletizing

Pelletizing is a mechanical process through which the co-compost mixture is compressed to make pellets. The prepared mixture is required to be fed to the machine manually at a controlled speed in order to avoid the overfeeding of the machine. Processed pellets are released through the vent while fine particles are sorted out through another output line. The pellets produced are collected into an end tray aligned with the pelletizer. After pelletization, the produced pellets may need air-drying, if its moisture content is high and also to avoid fungus germination in pellet products.

Figure 16: Feeding co-compost into the pelletizing machine

Figure 17: Produced Pellets

Note: With the installation of new pelletizer machine, it is expected to update this section with the corresponding data related to pelletizing process, value addition, production data etc.

Annexures

Table 1: Co-composting Check List

Step	Description	Yes/No
1	Transporting FS to the site	
2	Discharge FS in to the drying beds	
3	Keep FS in drying beds for 14-21 days	
4	Remove Dried FS (DFS)	
5	Piling up DFS	
6	Transporting MSW to the site	
7.	Sorting the waste in to categories E.g. Category 1 – Cardboard, Plastics, Polythene, Paper, PET bottles Category 2 – Banana leaves, coconut shells, coconut nuts Category 3 – kitchen waste, green leaves, market waste	
8.	Segregate category 3 waste as the input material for windrow composting	
9.	Building up a windrow pile – (Pile Dimension Height: 1-1.2m, Width 1- 3m)*	
10.	Check the moisture level of the pile daily: 1. Manually – by squeezing the composting material 2. With a moisture meter If water drips through fingers when squeezed, it indicate excessive moisture content, and if the material does not form a clump when squeezed, then the moisture content is considered to be too low. The optimum moisture level is in between 50-60%. If moisture level is less than 40%, add water up to 50-60 %.	
11.	Daily check the pile temperature by; 1. Manually - by inserting the hand into the pile and feeling the warmth 2. Using a Thermometer If the temperature rises up to 60-65 ^{0}C, turn the pile.	
12.	When temperature is stable, keep the compost pile static for 1 month	
13.	Sieve the compost	
14.	Weigh	
15.	Pack	

References

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