LAND AND WATER DISCUSSION PAPER

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On-farm composting methods

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WATER
DISCUSSION
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Preface

Composting is an attractive proposition for turning on-farm organic waste materials into a farm resource. However, farmers in many parts of the world, and especially in developing countries, are unable to make the best use of the composting opportunities available to them. This is because they face various constraints, among them a lack of awareness on efficient expeditious labour-saving technology.

Various workers have used a range of approaches to composting technology for different situations. However, the information on recently evolved composting methodologies, especially those suited to small farmers, remains scattered and needs consolidation. In order to address this issue, the Land and Water Development Division (AGL), FAO, organized an electronic conference titled ‘Organic recycling: on-farm composting methods’ from May 2002 to March 2003. The conference provided a platform for institutions/agencies and scientists to share information and exchange ideas, views and experiences on the subject. A background document reviewing approaches and methodologies was made available to the participants as a starting point for discussions.

This publication is the outcome of an amalgamation of the technical contents of the background paper, the inputs of the electronic conference and its further reinforcement by the literature update and analysis. The publication presents an overview of on-farm composting methodologies with special emphasis on rapid composting processes suited to small farmers in developing countries. It highlights the features of the various approaches and the improvements made to them over time.

The aim of the publication is to provide up-to-date information on compost production methodologies to the scientific community, extension workers, non-governmental organizations, farming communities and other stakeholders concerned with agricultural development. Furthermore, it is intended as an instrument for promoting the wide-scale adoption of efficient, rapid composting technologies, with the ultimate objectives of improving soil productivity in developing countries and protecting the environment from degradation.

Acronyms

C	Carbon
CFA	Compost fungus activator
CO_2	Carbon dioxide
EM	Effective micro-organism
IBS	Institute of Biological Sciences, the Philippines
K	Potassium
N	Nitrogen
NGO	Non-governmental organization
O	Oxygen
P	Phosphorus

Executive summary

Growing concerns relating to land degradation, the inappropriate use of inorganic fertilizers, atmospheric pollution, soil health, soil biodiversity and sanitation have rekindled global interest in organic recycling practices such as composting. The potential of composting to turn on-farm waste materials into a farm resource makes it an attractive proposition. Composting offers benefits such as enhanced soil fertility and soil health that engender increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a better environment. However, many farmers, and especially those in developing countries find themselves at a disadvantage as they fail to make the best use of organic recycling opportunities. These farmers work under various constraints relating to: a lack of knowledge on efficient expeditious technology; long time spans; intense labour, land and investment requirements; and economic factors.

As there is an extensive literature on composting methodology, this review presents only a selective and brief account of the salient approaches. It makes a broad distinction between small-scale and large-scale composting practices. While small-scale production systems normally employ infrastructure and techniques that are technically and financially more feasible to farmers, large-scale systems require investment for containers and/or turning, as well as greater knowledge and skills to control the process. Therefore, the former may serve individual small-scale composters as technology packages that are fine-tuned to suit specific circumstances, and the latter as a means to meet quantum requirements of an individual or group of individuals.

The review also makes a distinction between traditional and rapid composting practices. The distinction is based mainly on the difference between those practices adopted as a convention and recent introductions for expediting the process that entail individual or combined application of treatments such as shredding and frequent turning, mineral nitrogen compounds, effective micro-organisms, use of worms, cellulolytic organisms, forced aeration and mechanical turnings.

Traditional methods generally adopt an approach based on anaerobic decomposition or one based on aerobic decomposition using passive aeration through measures such as little and infrequent turnings or static aeration provisions such as perforated poles/pipes. These processes take several months. On the other hand, using the recently developed techniques mentioned above, rapid methods expedite the aerobic decomposition process and reduce the composting period to about four to five weeks. Most of these methods include a high temperature period and this adds further value to the product by eliminating pathogens and weed seeds.

Traditional methods based on passive composting involve stacking the material in piles or pits to decompose over a long period with little agitation and management. Using this approach, the Indian Bangalore method permits anaerobic decomposition for a larger part of operations and requires six to eight months to produce compost. The method is mainly used to treat urban wastes in the developing world. A similar method employed on large farms in the Western Hemisphere is passive composting of manure piles. The active composting period in this process may take one to two years.

The Indian Indore methods enhance passive aeration slightly through a few turnings, thereby permitting aerobic decomposition and enabling production in a time span of about four months.

The Chinese rural composting pit method uses a passive aeration approach through turnings to provide output in two to three months. The above methods are in widespread use in the developing world. Although the labour requirements for these methods are high, they are not capital intensive and do not require sophisticated infrastructure and machinery. Small farmers find them easy to practice, especially where manual labour is not a constraint. However, the low turnover and longer time span are the major drawbacks of these methods.

Rapid methods such as Berkley rapid composting and North Dakota State University hot composting involve accelerated aerobic decomposition using a range of measures: chopping raw materials into small pieces; using mineral compounds such as ammonium sulphate, chicken manure, and urine; and turning the material on a daily basis. While chopping without much mechanical support may be possible on a small scales, mechanization may be necessary for large-scale applications. While the Berkley rapid composting method claims an active composting period of two to three weeks owing to its extremely frequent turning, the North Dakota State University hot composting method may take four to six weeks.

The EM-based quick composting process involves aerobic decomposition of rice husk/bran, rice straw and cow dung as raw materials in pits or on a flat surface; and uses effective micro-organisms (EMs) as activator to expedite the decomposition process. The use of EMs as activator reduces the composting period from 12 to 4 weeks. An example of a method based on cellulolytic culture is the rapid composting approach developed by the Institute of Biological Sciences in the Philippines. Its salient features include: chopping of vegetative organic materials, stacking of materials in wind-rows, passive aeration through air ducts, and the use of cellulose decomposing fungus (*Trichoderma harzianum*). The process takes about four weeks.

Turned wind-rows have been in use on large farms for some time, especially in the developed world. The wind-rows are turned periodically using a bucket loader or special turning machine. The turning operation mixes the composting materials, enhances passive aeration and provides congenial conditions for aerobic decomposition. Composting operations may take up to eight weeks. Passively aerated wind-rows eliminate the need for turning by providing air to the materials via pipes, which serve as air ducts. The active composting period lasts 10–12 weeks.

Mechanical forced aeration methods such as the aerated static pile approach reduce composting time significantly, allow for higher, broader piles, and have lower land requirements compared with turned wind-row and passively aerated wind-row methods. However, there is little experience of using aerated static piles with agricultural wastes. The technology is commonly used for treating municipal sewage sludge. The active composting period may range from three to five weeks.

Mechanical forced aeration and accelerated mechanical turning methods such as in-vessel composting are specially-designed commercial systems whose potential advantages include: reduced labour, weatherproofing, effective process control, faster composting, reduced land requirements, and quality output. Among these systems, bin composting and rectangular agitated beds have become established on some large farms in the developed world. Bin composting involves: provision for forced aeration in the bin floor; little turning of the composting material; and the transfer of material from one bin to another. Although the initial high investment and recurring operation and maintenance costs involved in bin composting could limit its adoption, there are practices such as passively aerated bin composting of municipal waste (in Phnom Penh) that are technically and financially affordable for the developing world.

In addition, there is another recently introduced approach called vermicomposting. Vermicomposting is not composting as such because it is not the decomposition of organic materials by micro-organisms, but enzymatic degradation through the digestive system of earthworms. It is the casts of the worms that are utilized. Vermicomposting results in high-quality compost and does not require physical turning of the material. In order to maintain aerobic conditions and limit the temperature rise, the bed or pile of materials needs to be of limited size. Temperatures need to be regulated to favour the growth and activity of worms. However, it has a lower turnover than other rapid methods and the composting process takes 6–12 weeks.

In some circumstances, a combination of aerobic decomposition, anaerobic decomposition and vermicomposting may be useful for the more effective production of high-quality compost. Integrating traditional composting and vermicomposting is one such example. In this approach, while the high temperature ensures better quality through the destruction of pathogens and weed seeds, worms perform the roles of turning and maintaining an aerobic condition, thereby reducing the need for investment and labour.

Chapter 1
Composting process and techniques

Composting is the natural process of 'rotting' or decomposition of organic matter by micro-organisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting.

Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil: (i) becomes more resistant to stresses such as drought, diseases and toxicity; (ii) helps the crop in improved uptake of plant nutrients; and (iii) possesses an active nutrient cycling capacity because of vigorous microbial activity. These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers.

Types of composting

Composting may be divided into two categories by the nature of the decomposition process. In anaerobic composting, decomposition occurs where oxygen (O) is absent or in limited supply. Under this method, anaerobic micro-organisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. In the absence of O, these compounds accumulate and are not metabolized further. Many of these compounds have strong odours and some present phytotoxicity. As anaerobic composting is a low-temperature process, it leaves weed seeds and pathogens intact. Moreover, the process usually takes longer than aerobic composting. These drawbacks often offset the merits of this process, viz. little work involved and fewer nutrients lost during the process.

Aerobic composting takes place in the presence of ample O. In this process, aerobic micro-organisms break down organic matter and produce carbon dioxide (CO_2), ammonia, water, heat and humus, the relatively stable organic end product. Although aerobic composting may produce intermediate compounds such as organic acids, aerobic micro-organisms decompose them further . The resultant compost, with its relatively unstable form of organic matter , has little risk of phytotoxicity. The heat generated accelerates the breakdown of proteins, fats and complex carbohydrates such as cellulose and hemi-cellulose. Hence, the processing time is shorter. Moreover, this process destroys many micro-organisms that are human or plant pathogens, as well as weed seeds, provided it undergoes sufficiently high temperature. Although more nutrients are lost from the materials by aerobic composting, it is considered more efficient and useful than anaerobic composting for agricultural production. Most of this publication focuses on aerobic composting.

Composting objectives may also be achieved through the enzymatic degradation of organic materials as they pass through the digestive system of earthworms. This process is termed vermicomposting.

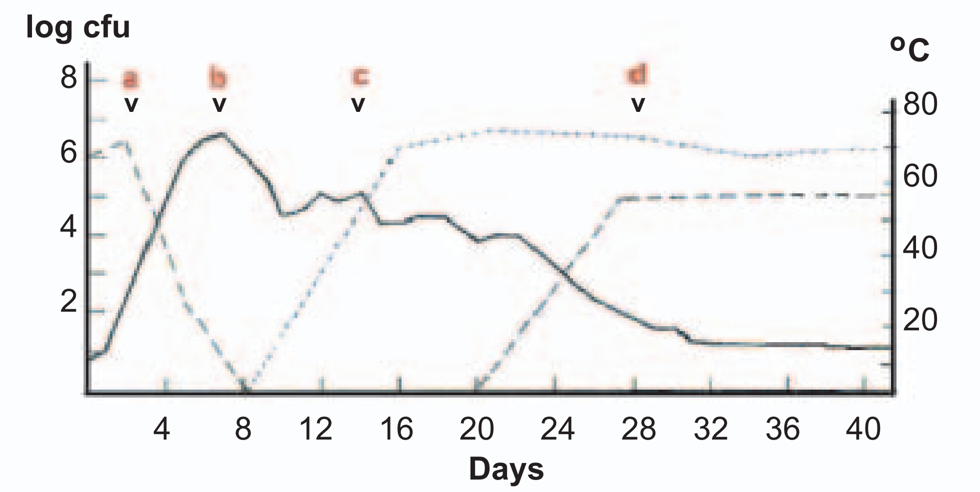
The aerobic composting process

The aerobic composting process starts with the formation of the pile. In many cases, the temperature rises rapidly to 70–80 °C within the first couple of days. First, mesophilic organisms (optimum growth temperature range = 20–45 °C) multiply rapidly on the readily available sugars and amino acids (Figure 1). They generate heat by their own metabolism and raise the temperature to a point where their own activities become suppressed. Then a few thermophilic fungi and several thermophilic bacteria (optimum growth temperature range = 50–70 °C or more) continue the process, raising the temperature of the material to 65 °C or higher. This peak heating phase is important for the quality of the compost as the heat kills pathogens and weed seeds.

The active composting stage is followed by a curing stage, and the pile temperature decreases gradually. The start of this phase is identified when turning no longer reheats the pile. At this stage, another group of thermophilic fungi starts to grow. These fungi bring about a major phase of decomposition of plant cell-wall materials such as cellulose and hemi-cellulose. Curing of the compost provides a safety net against the risks of using immature compost such as nitrogen (N) hunger, O deficiency , and toxic effects of organic acids on plants.

Eventually, the temperature declines to ambient temperature. By the time composting is completed, the pile becomes more uniform and less active biologically although mesophilic organisms recolonize the compost. The material becomes dark brown to black in colour. The particles reduce in size and become consistent and soil-like in texture. In the process, the amount

Figure 1
Temperature changes and fungi populations in wheat straw compost



Note:
Solid line = temperature; broken line = mesophilic fungi population; dotted line = thermophilic fungi population; left y-axis = fungal populations (logarithm of colony forming units (cfu) per gram of compost plated onto agar); right y-axis = temperature in centre of compost. a, b, c and d = heating phases.
Source: http://helios.bto.ed.ac.uk/bto/microbes/thermo.htm

of humus increases, the ratio of carbon to nitrogen (C:N) decreases, pH neutralizes, and the exchange capacity of the material increases.

Factors affecting aerobic composting

Aeration

Aerobic composting requires large amounts of O, particularly at the initial stage. Aeration is the source of O, and, thus, indispensable for aerobic composting. Where the supply of O is not sufficient, the growth of aerobic micro-organisms is limited, resulting in slower decomposition. Moreover, aeration removes excessive heat, water vapour and other gases trapped in the pile. Heat removal is particularly important in warm climates as the risk of overheating and fire is higher. Therefore, good aeration is indispensable for efficient composting. It may be achieved by controlling the physical quality of the materials (particle size and moisture content), pile size and ventilation and by ensuring adequate frequency of turning .

Moisture

Moisture is necessary to support the metabolic activity of the micro-organisms. Composting materials should maintain a moisture content of 40–65 percent. Where the pile is too dry, composting occurs more slowly, while a moisture content in excess of 65 percent develops anaerobic conditions. In practice, it is advisable to start the pile with a moisture content of 50–60 percent, finishing at about 30 percent.

Nutrients

Micro-organisms require C, N, phosphorus (P) and potassium (K) as the primary nutrients. Of particular importance is the C:N ratio of raw materials. The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable. Where the ratio is higher than 40:1, the growth of micro-organisms is limited, resulting in a longer composting time. A C:N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide, and odour can be a problem. The C:N ratio of the final product should be between about 10:1 and 15:1.

Temperature

The process of composting involves two temperature ranges: mesophilic and thermophilic. While the ideal temperature for the initial composting stage is 20–45 °C, at subsequent stages with the thermophilic organisms taking over, a temperature range of 50–70 °C may be ideal. High temperatures characterize the aerobic composting process and serve as signs of vigorous microbial activities. Pathogens are normally destroyed at 55 °C and above, while the critical point for elimination of weed seeds is 62 °C. Turnings and aeration can be used to regulate temperature.

Lignin content

Lignin is one of the main constituents of plant cell walls, and its complex chemical structure makes it highly resistant to microbial degradation (Richard, 1996). This nature of lignin has two implications. One is that lignin reduces the bioavailability of the other cell-wall constituents, making the actual C:N ratio (viz. ratio of biodegradable C to N) lower than the one normally cited. The other is that lignin serves as a porosity enhancer, which creates favourable conditions for aerobic composting. Therefore, while the addition of lignin-decomposing fungi may in some cases increase available C, accelerate composting and reduce N loss, in other cases it may result in a higher actual C:N ratio and poor porosity, both of which prolong composting time.

Polyphenols

Polyphenols include hydrolysable and condensed tannins (Schorth, 2003). Insoluble condensed tannins bind the cell walls and proteins and make them physically or chemically less accessible to decomposers. Soluble condensed and hydrolysable tannins react with proteins and reduce their microbial degradation and thus N release. Polyphenols and lignin are attracting more attention as inhibiting factors. Palm *et al*. (2001) suggest that the contents of these two substances be used to classify organic materials for more efficient on-farm natural resource utilization, including composting.

pH value

Although the natural buffering effect of the composting process lends itself to accepting material with a wide range of pH, the pH level should not exceed eight. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere.

Techniques for effective aerobic composting

Simple replication of composting practices does not always give the right answer to potential composters. This is because composting takes place at various locations and under diverse climates, using different materials with dissimilar physical, chemical and biological properties. An understanding of the principles and technical options and their appropriate application may be helpful in providing the optimal environment to the compost pile.

Improved aeration

In order to obtain the end product of uniform quality, the whole of the pile should receive a sufficient amount of O so that aerobic micro-organisms flourish uniformly. The methodologies deliberated in this publication made use of the techniques as presented below.

Pile size and porosity of the material

The size of the pile is of great significance and finds mention in the sections on passive composting of manure piles (Chapter 2) and turned wind-rows (Chapter 3). Where the pile or wind-row is too large, anaerobic zones occur near its centre, which slows the process in these zones. On the other hand, piles or wind-rows that are too small lose heat quickly and may not achieve a temperature high enough to evaporate moisture and kill pathogens and weed seeds. The optimal size of the piles and wind-rows should also consider such parameters as the physical property (porosity) of the materials and the way of forming the pile. While more porous materials allow bigger piles, heavy weights should not be put on top and materials should be kept as loose as possible. Climate is also a factor. With a view to minimizing heat loss, larger piles are suitable for cold weather. However, in a warmer climate, the same piles may overheat and in some extreme cases (75 °C and above) catch fire.

Ventilation

Provision of ventilation complements efforts to optimize pile size. Ventilation methods are varied. The simplest method is to punch holes in the pile at several points. The high temperature compost method of Chinese rural composting (Chapter 2) involves inserting a number of bamboo poles deep into the pile and withdrawing them a day later, leaving the pile with ventilation holes. Aeration is improved by supplying more air to the base of the pile where O deficiency occurs most often. In addition to the above-mentioned vertical poles, Ecuador on-farm composting (Chapter 2) uses a lattice of old branches at the base to allow more pile surface to come into contact with the air, and the composting period is reduced to two to three months in warm seasons. This technique is also practised in the rapid composting method developed by the Institute of Biological Sciences (IBS) in the Philippines (Chapter 2), where the platform should be 30 cm above the ground. The passively aerated wind-rows method (Chapter 3) uses a more sophisticated technique. It entails embedding perforated pipes throughout the pile. As the pipe ends are open, air flow is induced and O is supplied to the pile continuously. The aerated static pile method (Chapter 3) takes this aeration system a step further; a blower generates air flow to create negative pressure (suction) in the pile and fresh air is supplied from outside.

Turning

Once the pile is formed and decomposition starts, the only technique for improving aeration is turning. As Table 1 shows, frequency of turning is crucial for composting time. While the Indian Bangalore method (Chapter 2) requires six to eight months to mature, the Indian Coimbatore method (Chapter 2) (turning once) reduces the time to four months, and the Chinese rural composting pit method (turning three times) reduces the time to three months. An extreme example is the Berkley rapid composting method (Chapter 2), which employs daily turning to complete the process in two weeks. In some cases, turning not only distributes air throughout the pile, it also prevents overheating as it kills all the microbes in the pile and terminates decomposition. However, turning too frequently might result in a lower temperature.

Inoculation

While some composters find improved aeration enough for enhanced microbial activities, others may need inoculation of micro-organisms. Inoculum organisms utilized for composting are mainly fungi such as *Trichoderma* sp. (IBS rapid composting and composting weeds (Chapter 2)) and *Pleurotus* sp. (composting Coir Pith (Chapter 2) and composting weeds). This publication also features ‘effective micro-organisms’ (EMs) (EM-based quick compost production process (Chapter 2)). The inoculums are an affordable choice for those with access to the market and also for resource-poor farmers. The production cost could be reduced by using inoculums taken from compost pits (pit method of the Indian Indore method (Chapter 2)), by purchasing the commercial product and multiplying it on the farm (EM-based quick compost production process), and by utilizing native inoculums derived from soils or plant leaves.

Supplemental nutrition

The techniques mentioned above often need to be complemented by the provision of nutrients. One of the most common practices is to add inorganic fertilizers, particularly N, in order to modify a high C:N ratio. Similarly, P is sometimes applied as the C:P ratio of the material mix is also considered important (the ratio should be between 75:1 and 150:1). When micro-organisms

Table 1
Salient features of selected small-scale aerobic composting techniques

Method	Salient features					Duration
	Substrate size reduction	Turnings at intervals of (days)	Added aeration provision	Microbial inoculation	Supporting microbial nutrition	
Indore pit		+15, +30, +60		Inoculum from old pit		4 months
Indore heap	Shredded	+42, +84				4 months
Chinese pit		+30, +60, +75			Superphosphate	3 months
Chinese high temperature compost	Shredded	+15	Aeration holes in heap through bamboo poles / maize stalks		Superphosphate	2 months
Ecuador on-farm composting		+21	Lattice of old branches/ poles at heap base			2–3 months in summer; 5–6 months in winter
Berkley rapid composting	Shredded to small size	Daily or alternate day turning				2 weeks with daily turning & 3 weeks with alternate day turning
North Dakota State University hot composting	Shredded	+3 or +4	4–5 holes punched in centre of pile		0.12 kg N per 90 cm dry matter	4–6 weeks
EM-based quick composting		+14, +21		EM	Molasses	4–5 weeks
IBS rapid composting	Shredded	+7, +14, then every 2 weeks	Raised platform ground / perforated bamboo trunks	*Trichoderma* sp.		3–7 weeks

are inoculated, they require sugar and amino acids in order to boost their initial activities; molasses is often added for this purpose.

Shredding

Downsizing, or chopping up the materials, is a sound and widely-practised technique. It increases the surface area available for microbial action and provides better aeration. This technique is particularly effective and necessary for harder materials such as wood.

Other measures

An example of other measures mentioned in this publication is the practice of adding lime. Lime is thought to weaken the lignin structure of the plant materials and enhance the microbial population. However, in some cases, liming is not recommended as the pile may become too alkaline, resulting in significant N loss.

Chapter 2
Small-scale composting

Traditional methods

Anaerobic composting

Indian Bangalore method

This method of composting was developed at Bangalore in India in 1939 (FAO, 1980). It is recommended where night soil and refuse are used for preparing the compost. The method overcomes many of the disadvantages of the Indore method (below), such as the problem of heap protection from adverse weather, nutrient losses from high winds and strong sun, frequent turning requirements, and fly nuisance. However, the time required for the production of finished compost is much longer. The method is suitable for areas with scanty rainfall.

Pit preparation

Trenches or pits about 1 m deep are dug; the breadth and length of the trenches can vary according to the availability of land and the type of material to be composted. Site selection is as per the Indore method. The trenches should have sloping walls and a floor with a 90–cm slope to prevent waterlogging.

Filling the pit

Organic residues and night soil are put in alternate layers. After filling, the pit is covered with a layer of refuse of 15–20 cm. The materials are allowed to remain in the pit without turning and watering for three months. During this period, the material settles owing to reduction in biomass volume. Additional night soil and refuse are placed on top in alternate layers and plastered or covered with mud or earth to prevent loss of moisture and breeding of flies. After the initial aerobic composting (about eight to ten days), the material undergoes anaerobic decomposition at a very slow rate. It takes about six to eight months to obtain the finished product.

Passive composting of manure piles

Passive composting involves stacking the materials in piles to decompose over a long time with little agitation and management (NRAES, 1992). The process has been used for composting animal wastes. However, the simple placing of manure in a pile does not satisfy the requirements for continuous aerobic composting. Without considerable bedding material, the moisture content of manure exceeds the level that enables an open porous structure to exist in the pile. Little if any air passes through it. Under these circumstances, the anaerobic micro-organisms dominate the degradation. All of the undesirable effects associated with anaerobic degradation occur.

Where a livestock management system relies on bedding to add to livestock comfort and cleanliness, the bedding becomes mixed with the manure and creates a drier, more porous mixture.

This provides some structure and, depending on the amount of bedding, enables the mixture to be stacked in true piles. The bedding also tends to raise the C:N ratio of the manure.

A mixture of manure and bedding requires a considerable proportion of bedding to provide the porosity necessary for composting. At least equal volumes of bedding and manure are required. Where the amount of bedding is insufficient to provide a porous mix, additional dry amendments must be provided by either increasing the bedding used in the barn or adding amendments when piles are formed. Manure from horse stables or bedded manure packs (animal bedding and manure mixture) can often compost in piles alone, whereas non-bedded manure from dairy, swine and many poultry barns needs drying or additional amendments.

The pile must be small enough to allow passive air movement, generally less than 2 m high and 4 m wide. This passive method of composting is essentially wind-row composting but with a much less frequent turning schedule. It is a common method for composting leaves. It demands minimal labour and equipment. Passive composting is slow because of its low aeration rate, and the potential for odour problems is greater.

Aerobic composting through passive aeration

Indian Coimbatore method

This method (Manickam, 1967) involves digging a pit (360 cm long × 180 cm wide × 90 cm deep) in a shaded area (length can vary according to the volume of waste materials available). Farm wastes such as straw, vegetable refuse, weeds and leaves are spread to a thickness of 15–20 cm. Wet animal dung is spread over this layer to a thickness of 5 cm. Water is sprinkled to moisten the material (50–60 percent of mass). This procedure is repeated until the whole mass reaches a height of 60 cm above ground. It is then plastered with mud, and anaerobic decomposition commences. In four weeks, the mass becomes reduced and the heap flattens. The mud plaster is removed and the entire mass is turned. Aerobic decomposition commences in at this stage. Water is sprinkled to keep the material moist. The compost is ready for use after four months.

Indian Indorepit method

An important advance in the practice of composting was made at Indore in India by Howard in the mid-1920s. The traditional procedure was systematized into a method of composting now known as the Indore method (FAO, 1980).

Raw materials

The raw materials used are mixed plant residues, animal dung and urine, earth, wood ash and water. All organic material wastes available on a farm, such as weeds, stalks, stems, fallen leaves, prunings, chaff and fodder leftovers, are collected and stacked in a pile. Hard woody material such as cotton and pigeon-pea stalks and stubble are first spread on the farm road and crushed under vehicles such as tractors or bullock carts before being piled. Such hard materials should not exceed 10 percent of the total plant residues. Green materials, which are soft and succulent, are allowed to wilt for two to three days in order to remove excess moisture before stacking; they tend to pack closely when stacked in the fresh state. The mixture of different kinds of organic material residues ensures a more efficient decomposition. While stacking, each type of material is spread in layers about 15 cm thick until the heap is about 1.5 m high. The heap is then cut into vertical slices and about 20–25 kg are put under the feet of cattle in the shed as bedding for the night. The next morning, the bedding, along with the dung and urine and urine-earth, is taken to the pits where the composting is to be done.

Pit site and size

The site of the compost pit should be at a level high enough to prevent rainwater from entering in the monsoon season; it should be near the cattle shed and a water source. A temporary shed may be constructed over it to protect the compost from heavy rainfall. The pit should be about 1 m deep, 1.5–2 m wide, and of a suitable length.

Filling the pit

The material brought from the cattle shed is spread in the pit in even layers of 10–15 cm. A slurry made from 4.5 kg of dung, 3.5 kg of urine-earth and 4.5 kg of inoculum from a 15–day–old composting pit is spread on each layer. Sufficient water is sprinkled over the material in the pit to wet it. The pit is filled in this way, layer by layer, and it should not take longer than one week to fill. Care should be taken to avoid compacting the material in any way.

Turning

The material is turned three times while in the pit during the whole period of composting: the first time 15 days after filling the pit; the second after another 15 days; and the third after another month. At each turning, the material is mixed thoroughly and moistened with water.

Indian Indore heap method

Heap site and size

During rainy seasons or in regions with heavy rainfall, the compost may be prepared in heaps above ground and protected by a shed. The pile is about 2 m wide at the base, 1.5 m high and 2 m long. The sides taper so that the top is about 0.5 m narrower than the base. A small bund is sometimes built around the pile to protect it from wind, which tends to dry the heap.

Forming the heap

The heap is usually started with a 20 cm layer of carbonaceous material such as leaves, hay, straw, sawdust, wood chips and chopped corn stalks. This is covered with 10 cm of nitrogenous material such as fresh grass, weeds or garden plant residues, fresh or dry manure or digested sewage sludge. The pattern of 20 cm of carbonaceous material and 10 cm of nitrogenous material is repeated until the pile is 1.5 m high and the material is normally wetted until it feels damp but not soggy. The pile is sometimes covered with soil or hay to retain heat and it is turned at intervals of 6 and 12 weeks. In the Republic of Korea, the heaps are covered with thin plastic sheets to retain heat and prevent insect breeding.

Where materials are in short supply, the alternate layers can be added as they become available. Moreover, all the materials can be mixed together in the pile provided that the proper proportions are maintained. Shredding the material speeds up decomposition considerably. Most materials can be shredded by running a rotary mower over them several times. Where sufficient nitrogenous material is not available, a green manure or leguminous crop such as sun hemp is

Plate 1
Tipping organic wastes into a pit; they are spread out into an even layer
[FAO]

grown on the fermenting heap by sowing seeds after the first turning. The green matter is then turned in at the time of the second mixing. The process takes about four months to complete.

Chinese rural composting – pit method

Under this method, the composting is generally carried out in a corner of a field in a circular or rectangular pit (FAO, 1980). Rice straw, animal dung (usually pig), aquatic weeds and green manure crops are used. Silt pumped from river beds is often mixed with the crop residues. The pits are filled layer by layer, each layer being 15 cm thick. Usually, the first layer is a green manure crop or water hyacinth, the second layer is a straw mixture (Plate 1) and the third layer is animal dung. These layers are alternated until the pit is full, when a top layer of mud is added. A water layer of about 4 cm deep is maintained on the surface to create anaerobic conditions, which helps to reduce N losses. The approximate quantities of the different residues in terms of tonnes per pit are: river silt 7.5, rice straw 0.15, animal dung 1.0, aquatic plants or green manure 0.75, and superphosphate 0.02. In total, there are three turnings. The first turning is given one month after filling the pit and, at this time, the superphosphate is added and mixed in thoroughly. Water is added as necessary. The second turning is done after another month and the third two weeks later. The material is allowed to decompose for three months and produces about 8 tonnes of compost per pit.

Rapid methods

Aerobic high temperature composting

Chinese rural composting – high temperature method

This form of compost is prepared mainly from night soil, urine, sewage, animal dung, and chopped plant residues at a ratio of 1:4. The materials are heaped in alternate layers starting with chopped plant stalks and followed by human and animal wastes; water is added to an optimal amount.

At the time of making the heap, a number of bamboo poles are inserted for aeration purposes. Once the heap formation is complete, it is sealed with 3 cm of mud plaster. The bamboo poles are withdrawn on the second day of composting, leaving the holes to provide aeration. Within four to five days, the temperature rises to 60–70 °C and the holes are then sealed. The first turning is usually done after two weeks and the moisture is made up with water or animal or human excreta; the turned heap is again sealed with mud. The compost is ready for use within two months.

In some locations, a modified method of high temperature composting is used. The raw materials, crop stalks (30 percent), night soil (30 percent) and silt (30 percent), are mixed with superphosphate at the rate of 20 kg of superphosphate per tonne of organic material. The compost heaps have aerating holes made by inserting bundles of maize stalks instead of bamboo poles.

Ecuador on-farm composting

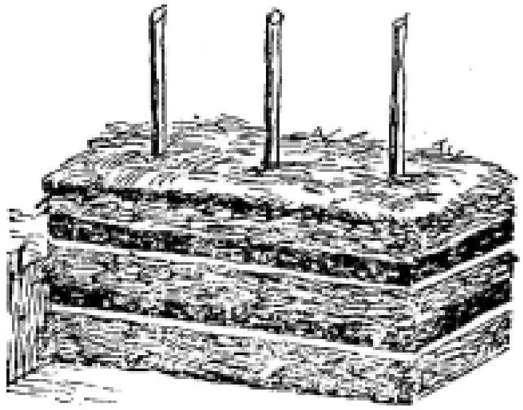
Under this method , the raw materials utilized for compost making are:

- animal manure: from cows, pigs, poultry, horses, donkeys, ducks, etc.;
- crop residues and weeds: maize, bean, broad bean, groundnut, coffee and weeds;
- agro-industrial wastes, ash and phosphate rock;
- wood cuttings;
- topsoil from the forest or from an uncultivated or sparingly cultivated area;
- freshwater.

The raw materials are put in layers in the following sequence (Figure 2):

- a layer of crop residues (20 cm);
- a layer of topsoil (2 cm);
- a layer of manure (5–10 cm).

FIGURE 2
Ecuador heap composting



Ash or phosphate rock (50 g/m^2) is then spread on the surface, and freshwater is sprinkled on the material.

The above steps are repeated until a height of about 1–1.2 m is reached. It is recommended to begin the heap by constructing a lattice of old branches, and to place two or three woodcuttings vertically along the lattice in order to facilitate ventilation. The heap should be 2 m × 1–1.2 m × 1–1.2 m. Once a week water should be added to the heap. However, too much water could lead to the leaching of nutrients. After three weeks, the heap must be mixed to ensure that all materials reach the centre. During the process, the temperature rises to 60–70 °C, and most weed seeds and pathogens are killed. While it may take about two to three months to prepare the compost in a warm climate, in cold regions it could take five to six months.

Berkley rapid composting method – shredding and frequent turning

This method (Raabe, 2001) corrects some of the problems associated with the earlier methods of composting. The process can produce compost in two to three weeks. Several factors are essential to the rapid composting method:

- Material composts best when it is 1.25–3.75 cm in size. Soft, succulent tissues do not need chopping into very small pieces because they decompose rapidly. The harder or woodier the tissues, the smaller they need to be in order to decompose rapidly. Woody material should be passed through a grinder. Chopping material with a sharp shovel is effective. When pruning plants, the material should be cut into small pieces using the pruning shears. This requires a little effort but the results are worth it

- For the composting process to work most effectively, the material to be composted should have a C:N ratio of 30:1. Mixing equal volumes of green plant material with equal volumes of naturally dry plant material yields such a ratio. The green material can be grass clippings, old flowers, green prunings, weeds, fresh garbage and fruit and vegetable wastes. The dried material can be fallen leaves, dried grass, straw and woody materials from prunings.

- Materials that should not be added to a composting pile include: soil, ashes from a stove or fireplace, and manure from carnivorous animals. Manures from herbivorous animals such as rabbits, goats, cattle, horses, elephants and fowl can be used. Once a pile has been started, nothing should be added. This is because it takes a certain length of time for the material to break down and anything added has to start at the beginning, thus lengthening the decomposition time for the whole pile. Excess material should be as dry as possible during storage until a new pile is started. Moist stored materials start to decompose. If this occurs, they will not be effective in the compost pile. Nothing needs to be added to the organic materials to make them decompose. The micro-organisms active in the decomposition process are ubiquitous where plant materials are found and develop rapidly in any compost pile.

- Composting works best where the moisture content of materials in the pile is about 50 percent. Too much moisture creates a soggy mass, and decomposition will then be slow and the pile will smell. Where the organic material is too dry, decomposition is either very slow or does not occur at all.

- Heat, which is very important in rapid composting, is supplied by the respiration of the micro-organisms as they break down the organic materials. To prevent heat loss and to build up the amount of heat necessary, a minimum volume of material is essential. The pile should be at least 90 cm × 90 cm × 90 cm in size. Where the dimensions are less than 80 cm, the rapid process will not occur. Heat retention is better in bins than in open piles, so rapid composting is more effective where bins are used. In addition, the use of bins is much neater. High temperatures favour the micro-organisms that are the most rapid decomposers; these micro-organisms function at about 71 °C and a good pile maintains itself at about that temperature.

- The compost pile needs to be turned to prevent it from overheating. If the temperature in the pile rises much above 71 °C, the micro-organisms will be killed, the pile will cool, and the whole process will have to start again from the beginning. Turning the pile prevents overheating and aerates the pile, both necessary conditions for keeping the most active decomposers functioning. The pile should be turned in a manner that the material is moved from the outside to the centre. In this way, all the material reaches optimal temperatures at various times. Owing to heat loss around the margins, only the central portion of the pile is at the optimal temperature. Because of the need for turning, it is desirable to have two bins so that the material can be turned from one into another. Bins with removable slats in the front facilitate the turning process. Bins with covers retain the heat better than those without. Once the decomposition process starts, the pile becomes smaller and, because the bin is no longer full, some heat will be lost at the top. This can be prevented by using a piece of polyethylene plastic slightly larger than the top area of the bin. After the compost has been turned, the plastic is placed directly on the top of the compost and is tucked in around the edges. If the material in the pile is turned every day, it will take two weeks or a little longer to compost. If turned every other day, it will take about three weeks. The longer the interval between turning, the longer it will take for the composting to finish.

- If the procedure is followed properly, a pile heats to a high temperature within 24–48 hours. If it does not do so, this means that the pile is too wet or too dry or that there is not enough green material (or N) present. If too wet, the material should be spread out to dry. If too dry, moisture should be added. If neither of these, then the N is low (a high C:N ratio), and this can be corrected by adding materials high in N (such as ammonium sulphate, grass clippings, fresh chicken manure or urine diluted 1 to 5).
- Where the C:N ratio is less than 30:1, the organic matter decomposes very rapidly but there is a loss of N. This is given off as ammonia, and where this odour is present in or around a composting pile, it means that valuable N is being lost in the air. This can be counteracted by adding sawdust to that part of the pile where there is an ammonia odour (sawdust is very high in C and low in N). Some covering for the pile may be necessary in order to keep the composting materials from becoming too wet during the rainy season.
- The rapid decomposition can be detected by a pleasant odour, by the heat produced (visible in the form of water vapour given off during the turning of the pile), by the growth of white fungi on the decomposing organic material, by a reduction of volume, and by the materials changing colour to dark brown. As composting nears completion, the temperature drops and, finally, little or no heat is produced. The compost is then ready to use. If the material was not chopped into small pieces during the preparation phase, screening the material through 2.5–cm–mesh chicken wire will hold back the large pieces. These can be added to the next pile and eventually they will decompose.

North Dakota State University hot composting – use of mineral nitrogen activator

Under this method (Smith, 1995), compost piles with a height of 1.8 m are raised. The maximum size of the organic matter pieces should be 15–23 cm long. Where bins are constructed, dimensions of about 152 × 152 × 183 cm yield 4.3 m^3 of compost in four to six weeks.

To keep the aerobic bacteria population high and active, proportionate amounts of nitrogenous fertilizer should be added (0.12 kg of fertilizer per 0.0283 m^3 of dry matter) and four or five holes punched into the centre of the pile. This is best done in phases or stages as the compost pile is building up. For example, for 4.3 m^3 of dry matter, where the pile is built up over a period of three stages at 60, 120 and 180 cm, 5.7 kg of N fertilizer should be added at each step. The total should be about 17–18 kg of fertilizer for the entire pile.

In this high temperature, bacterially active system, it is best to turn the composting material every three or four days. Once activated, the temperature range should be 49–71 °C. The decomposition happens more rapidly in summer (as short as three to four weeks) and take more time in spring and autumn. No measurable activity occurs during typical winters in North Dakota, the United States of America. Once the compost is no longer hot and is an odour-free, crumbling material, it is ready for use.

Composting organic materials with high lignin content – lime treatment

By adding organic wastes such as sawdust, wood shavings, coir pith, pine needles, and dry fallen leaves, while preparing organic waste mixtures for composting, one can ensure that the compost produced contains sufficient and long-lasting humus. However, gardeners often find that where they use lignin-rich plant materials, the compost does not ripen rapidly. A technique for making good compost from hard plant materials involves mixing lime in a ratio of 5 kg per 1 000 kg of waste material. Lime can be applied as dry powder or after mixing with a sufficient quantity of water. Treatment with lime enhances the process of decomposition of hard materials . Liming can enhance the humification process in plant residues by enhancing microbial population and activity and by weakening lignin structure. It also improves the humus quality by changing the ratio of humic to fulvic acids and decreases the amount of bitumen, which interferes with the decomposition process. Instead of lime, powdered phosphate rock can be used in a ratio of 20 kg per 1 000 kg of organic waste. Phosphate rock contains a lot of lime. The phosphates and micronutrients contained in phosphate rock make composts rich in plant nutrients.

Aerobic high temperature composting with inoculation

EM-based quick composting

Effective micro-organisms (EM) consist of common and food-grade aerobic and anaerobic micro-organisms: photosynthetic bacteria, lactobacillus, streptomyces, actinomycetes, yeast, etc. The strains of the micro-organisms are commonly available from microbe banks or from the environment. There are no genetically engineered strains that are in use. Since 1999, seven small-scale organic fertilizer units have been using the EM-based quick production process in Myanmar (FAO, 2002). They are owned and operated by women's income generation groups. A unit consists of nine pits measuring about 180 cm (length) × 120 cm (width) × 90 cm (depth), enclosed by low walls and covered with a roof (Plate 2).

Raw materials

The raw materials for organic fertilizer production are:

- cow dung – 2 portions;
- rice husk – 1 portion;
- rice husk–charcoal – 1 portion;

Plate 2
EM-based quick composting in Myanmar
[Hiraoka]

- rice bran, milled – 1 portion;
- accelerator – 33 litres of EM solution or *Trichoderma* solution per pit.

Preparation of EM solution (accelerator)

One litre of 'instant solution' is made by mixing 10 ml of EM, 40 ml of molasses and 950 ml of water and leaving it for five to seven days, depending on temperature. The solution is then added to 1 litre of molasses and 98 litres of water to obtain 100 litres of ready-to-use EM solution. This amount is enough for three pits. The EM solution functioning as accelerator reduces the composting period from three months to one month.

Proced\ure

All the ingredients are mixed together, except accelerator. A 15 cm layer of mixture is spread in the pit and accelerator is sprinkled on it. This procedure is repeated until the pit is full. The pit is covered with a plastic sheet (Plate 3). Two or three weeks later, the whole pit is mixed in order to boost aerobic decomposition. The compost is ready to use a couple of weeks later. A pit produces 900 kg of final product per batch. The product is usually packed in 30–kg plastic bags. Assuming that it takes 30 days on average to produce a batch and that only eight pits may be used for technical reasons, the annual potential production capacity is 86.4 tonnes (0.9 tonnes × 8 pits × 12 months).

Plate 3
Compost pits
[Hiraoka]

Within the framework of the FAO Technical Cooperation Programme project on promotion of organic fertilizers in Lao PDR (TCP/LAO/2901), a simple EM-based quick composting method, as detailed below, is promoted.

Raw materials

The raw materials for compost production are:
- rice straw;
- farmyard manure;
- urea fertilizer;
- EM solution.

Procedure

Straw is stacked in layers of 20 cm height , 1 m width, and 5 m length to form a pile. A unit pile is about 5 m (length) × 1 m (width) × 1 m (height) in size. The pile is sprinkled with water (Plate 4) for adequate moisture content, followed by addition of a manure layer 5 cm high, and the sprinkling of a few handfuls of urea (100–200 g). EM solution, prepared in the same way as described in the Myanmar example, is sprinkled to accelerate aerobic decomposition.

Plate 4
Compost pile in preparation
[Singvilay (TCP/LAO/2901), Lao PDR]

Plate 5
The pile is covered with a plastic sheet after attaining the desired height
[Singvilay (TCP/LAO/2901), Lao PDR]

Plate 6
The pile is being turned
[Singvilay (TCP/LAO/2901), Lao PDR]

This procedure is repeated until the pile is about 1 m high and then it is covered with a plastic sheet (Plate 5). The pile is turned after two weeks (Plate 6) and then again after another week. Normally, the compost is ready two weeks later when the heap has cooled down and the height of the pile has fallen to about 70 cm.

IBS rapid composting

The IBS rapid composting technology (Virginia, 1997) involves inoculating the plant substrates used for composting with cultures of *Trichoderma harzianum*, a cellulose decomposer fungus.

The fungus, grown in a medium of sawdust mixed with the leaves of a leguminous tree called ipil ipil (*Leucaena leucocephala)*, is termed compost fungus activator (CFA). The technology is a development of the wind-row type of composting. Using this procedure, the composting time ranges from 21 to 45 days depending on the plant substrates used.

The procedure consists of two parts: the production of the CFA, and the composting process.

Preparation of substrates

Substrates such as rice straw, weeds and grasses should be chopped. Chopping helps speed up decomposition by increasing the surface area available for microbial action and providing better aeration. Where large quantities of substrates are to be used (i.e. several tonnes), a forage cutter/chopper is needed. Chopping can be dispensed with where the compost is not needed in the near future.

Adjustment of moisture content

Substrates should be moistened with water. Plant substrates can be soaked overnight in a pond, which reduces the need for water. Where a large volume of substrates are to be composted, a sprinkler is more convenient.

The compost mixture

Carbonaceous substrates should be mixed with nitrogenous ones at a ratio of 4:1 or less, but never lower than 1:1 (on a dry weight basis). Some possible combinations are:

- 3 parts rice straw to 1 part ipil ipil;
- 4 parts rice straw to 1 part chicken manure;
- 4 parts grasses to 1 part legume materials + 1 part manure;
- 4 parts grasses to 1 part *Chromolaena odorata* (a common broad-leaf weed) or *Mikania cordata* (a herbaceous climbing plant) + 1 part animal manure; it is important to use grasses and weeds that do not have flowers or seeds.

Composting procedure

The substrates should be piled loosely in a compost pen to provide better aeration within the heap. The material should not be too compact and no heavy weights should be placed on top. Compost heaps should be located in shady areas, e.g. under large trees. The platform should be raised about 30 cm from the ground in order to provide adequate aeration at the bottom. Alternatively, aeration can be provided by placing perforated bamboo trunks horizontally and vertically at regular intervals.

The CFA is broadcast onto the substrates during piling. The amount of activator used is usually 1 percent of the total weight of the substrates (i.e. about 1 kg compost activator per 100 kg substrate). Decomposition is faster where the activator is mixed thoroughly with the substrate. A larger amount of activator can be used should faster decomposition be desired.

The heap should be covered over completely. This maintains the heat of decomposition, and minimizes water evaporation and ammonia volatilization. White plastic sheets, or plastic sacks with their seams opened and sewn together, can serve as a cover. The compost heap usually heats up in 24–48 hours.

The temperature should be maintained at 50 °C or higher, and the heap should be turned every five to seven days for the first two weeks, and thereafter once every two weeks. After the first week, the volume of the pile should be reduced by one-third. After two weeks, the volume of the pile should be reduced to one-half the original volume.

The mature compost should be removed from the pen and dried in the sun for two days. It should then be put into sacks and stored in a shaded area. Decomposition should be allowed to continue until the substrate is finely fragmented, so that the finished product has a powdery texture. When decomposition is complete, the compost should be sun-dried again until the moisture content is 10–20 percent.

Where mature compost is needed at once, it should be sun-dried for one day as soon as its temperature drops to 30 °C. Drying removes excess moisture and makes the compost much easier to handle. Although the compost still retains some fibres, it can be applied immediately as fertilizer.

In the large-scale commercial production of compost, the following operations need to be mechanized (other steps remaining the same):

- Chopping of substrates – a forage cutter/chopper could be used.
- Mixing/turning – where there are several tonnes of substrate, a pay loader facilitates mixing of substrates and turning of heaps.
- A hammer mill should be used to break up large lumps of mature compost before drying.
- During rainy months, it is more economical to dry compost mechanically rather than in the sun.

Composting organic materials with high lignin content – coir pith

Coir pith is a waste from the coir industry (TNAU, 1999). This is a major industry that produces coconuts on a large scale. During the process of separating fibre from the coconut husk, a large volume of pith is collected. The pith, containing about 30 percent lignin and 26 percent cellulose, does not degrade rapidly, posing a major disposal problem. However, it can be composted by using the fungus *Pleurotus* sp. and urea. To compost 1 tonne of coir pith, the materials required are: five spawn bottles (250 g) of *Pleurotus* sp. and 5 kg of urea

The first step in the compost preparation is to select an elevated shaded place, or to erect a thatched shed. The surface is then levelled and an area 500 cm × 300 cm is marked out. To start with, about 100 kg of coir pith is spread. About 50 g of *Pleurotus* spawn is spread over this layer. About 100 kg of coir pith is spread on that. On this layer, 1 kg of urea is spread uniformly. The process is repeated until all the pith (1 tonne) is utilized. Water is sprinkled repeatedly so as to maintain the moisture optimum of 50 percent. Well-decomposed black compost is ready in about a month. The C:N ratio falls to about 24:1 and the N content rises from 0.26 to 1.06 percent.

Composting weeds

This method has been developed for composting weeds such as parthenium, water hyacinth (*Eichornia crassipes*), cyperus (*Cyperus rotundus*) and cynodon (*Cynodon dactylon*). The materials required are: 250 g of *Trichoderma viride* and *Pleurotus sajor-caju* consortia, and 5 kg of urea. An elevated shaded place is selected, or a thatched shed is erected. An area of 500 cm × 150 cm is marked out. The material to be composted is cut to 10–15 cm in size. About 100 kg of cut material is spread over the marked area. About 50 g of microbial consortia is sprinkled over this layer. About 100 kg of weeds are spread on this layer. One kilogram of urea is sprinkled uniformly over the layer. This process is repeated until the level rises to 1 m. Water is sprinkled as necessary to maintain a moisture level of 50–60 percent. Thereafter, the surface of the heap is covered with a thin layer of soil. The pile requires a thorough turning on the twenty-first day. The compost is ready in about 40 days.

Compost enrichment

Farm compost is poor in P content (0.4–0.8 percent). Addition of P makes the compost more balanced, and supplies nutrient to micro-organisms for their multiplication and faster decomposition. The addition of P also reduces N losses. Compost can be enriched by:

- Application of superphosphate, bonemeal or phosphate rock (Ramasami, 1975): 1 kg of superphosphate or bonemeal is applied over each layer of animal dung. Low-grade phosphate rock can also be used for this purpose.
- Use of animal bones: these can be broken into small pieces, boiled with wood ash leachate or lime water and drained, and the residue applied to the pits. This procedure of boiling bones facilitates their disintegration. Even the addition of raw bones, broken into small pieces and added to the pit, improves the nutrient value of compost significantly.
- Wood ash waste can also be added to increase the K content of compost.
- Addition of N-fixing and P-solubilizing cultures (IARI, 1989): The quality of compost can be further improved by the secondary inoculation of Azotobacter, Azospirillum lipoferum, and Azospirillum brasilence (N fixers); and Bacillus megaterium or *Pseudomonas* sp. (P solubilizers). These organisms, in the form of culture broth or water suspension of biofertilizer products, can be sprinkled when the decomposing material is turned after one month. By this time, the temperature of the compost has also stabilized at about 35 °C. As a result of this inoculation, the N content of straw compost can be increased by up to 2 percent. In addition to improving N content and the availability of other plant nutrients, these additions help to reduce the composting time considerably.

Chapter 3
Large-scale composting

Wind-row composting

Turned wind-rows

Wind-row composting consists of placing the mixture of raw materials in long narrow piles called wind-rows (Plate 7) that are agitated or turned on a regular basis (NRAES, 1992). The turning operation mixes the composting materials and enhances passive aeration. Typically, the wind-rows are from 90 cm high for dense materials such as manures to 360 cm high for light, voluminous materials such as leaves. They vary in width from 300 to 600 cm. The equipment used for turning determines the size, shape and spacing of the wind-rows. Bucket loaders with a long reach can build high wind-rows. Turning machines produce low, wide wind-rows.

Wind-rows aerate primarily by natural or passive air movement (convection and gaseous diffusion). The rate of air exchange depends on the porosity of the wind-row. Therefore, the size of a wind-row that can be aerated effectively is determined by its porosity. A wind-row of leaves can be much larger than a wet wind-row containing manure. Where the wind-row is too large, anaerobic zones occur near its centre. These release odours when the wind-row is turned. On the other hand, small wind-rows lose heat quickly and may not achieve temperatures high enough to evaporate moisture and kill pathogens and weed seeds.

For small- to moderate-scale operations, turning can be accomplished with a front-end loader or a bucket loader on a tractor. The loader lifts the materials from the wind-row and spills them down again, mixing the materials and reforming the mixture into a loose wind-row. The loader can exchange material from the bottom of the wind-row with material on the top by forming a new wind-row next to the old one. In order to minimize compaction, this needs to be done without driving onto the wind-row. Wind-rows turned with a bucket loader are often constructed in closely spaced pairs and then combined after the wind-rows shrink in size. Where additional mixing of the materials is desired, a loader can be used in combination with a manure spreader.

Plate 7
Wind-rows on a farm
[NRAES-114, 1999; courtesy: R. Rynk]

There are a number of specialized machines for turning wind-rows that reduce the time and labour involved considerably, mix the materials thoroughly, and produce a more uniform compost. Some of these machines attach to farm tractors or front-end loaders, others are self-propelled. A few machines can also load trucks and wagons from the wind-row.

It is very important to maintain a schedule of turning. The frequency of turning depends on the rate of decomposition, the moisture content and porosity of the materials, and the desired composting time. Because the decomposition rate is greatest at the start of the process, the frequency of turning decreases as the wind-row ages. Easily degradable or high N mixes may require daily turnings at the start of the process. As the process continues, the turning frequency can be reduced to a single turning per week.

In the first week of composting, the height of the wind-row diminishes appreciably and by the end of the second week it may be as low as 60 cm. It may be prudent to combine two wind-rows at this stage and continue the turning schedule as before. Consolidation of wind-rows is a good wintertime practice for retaining the heat generated during composting. This is one of the advantages of wind-row composting. It is a versatile system that can be adjusted to different conditions caused by seasonal changes.

With the wind-row method, the active composting stage generally lasts three to nine weeks depending upon the nature of the materials and the frequency of turning. Eight weeks is usual for manure composting operations. Where three weeks is the goal, the wind-row requires turning once or twice per day during the first week and every three to five days thereafter.

Passively aerated wind-rows

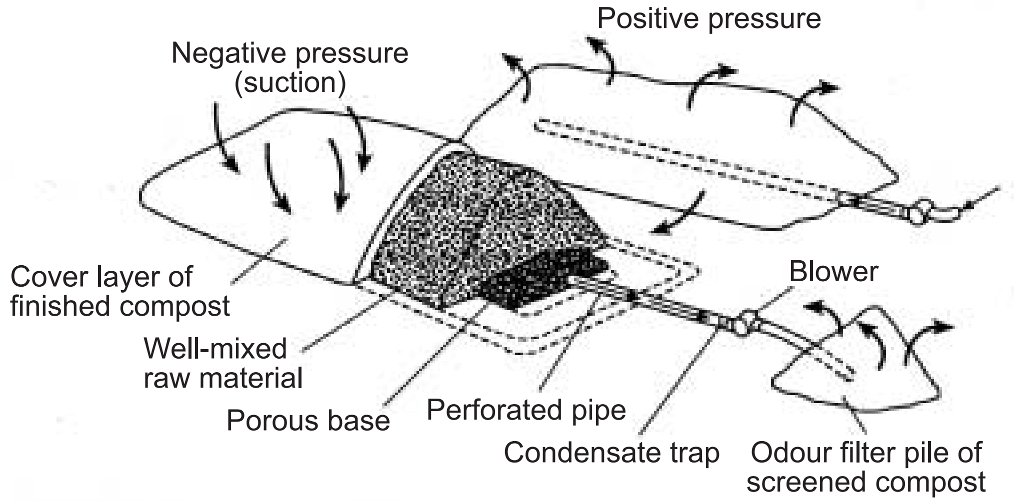
Under the passively aerated wind-row method, air is supplied to the composting materials through perforated pipes embedded in each wind-row, thereby eliminating the need for turning. The pipe ends are open. Air flows into the pipes and through the wind-row because of the chimney effect created as the hot gases rise upward out of the wind-row.

The wind-rows should be 90–120 cm high, built on top of a base of straw, peat moss or finished compost to absorb moisture and insulate the wind-row. The covering layer of peat or compost also insulates the wind-row, discourages flies, and helps to retain moisture, odour and ammonia. The plastic pipe is similar to that used for septic-system leach fields with two rows of 1.27–cm diameter holes drilled in the pipe. In many aerated pile applications, the pipe holes are oriented downward to minimize plugging and allow condensate to drain. However, some researchers recommend that the holes face upwards.

The wind-rows are generally formed by the procedures described for the aerated static pile method. Because the raw materials are not turned after the wind-rows are formed, they must be mixed thoroughly before they are placed in the wind-row. It is important to avoid compaction of materials while constructing the wind-row. Aeration pipes are placed on top of the peat/compost base. When the composting period is completed, the pipes are removed, and the base material is mixed with the compost.

This method has been studied and used in Canada for composting seafood wastes with peat moss, manure slurries with peat moss, and solid manure with straw or wood shavings. Manure from dairy, beef, swine and sheep operations has been used.

FIGURE 3
Aerated static pile layout



Source: NRAES-114, 1999.

Aerated static pile

The aerated static pile method takes the piped aeration system a step further, using a blower to supply air to the composting materials. The blower provides direct control of the process and allows larger piles. No turning or agitation of the materials occurs once the pile is formed. When the pile has been formed properly and where the air supply is sufficient and the distribution uniform, the active composting period is completed in about three to five weeks.

With the aerated static pile technique, the raw material mixture is piled over a base of wood chips, chopped straw or other very porous material (Figure 3). The porous base material contains a perforated aeration pipe. The pipe is connected to a blower, which either pulls or pushes air through the pile.

The initial height of the piles should be about 150–245 cm high, depending on: material porosity, weather conditions, and the reach of the equipment used to build the pile. Extra height is advantageous in the wintertime as it helps retain heat. It may be necessary to top off the pile with 15 cm of finished compost or bulking agent. The layer of finished compost protects the surface of the pile from drying, insulates it from heat loss, discourages flies, and filters ammonia and potential odours generated within the pile.

There are two common forms of aerated static piles: individual piles and extended piles. Individual piles are long triangular piles with a width (about 300–490 cm, not including the cover) equal to about twice the height of the pile. The aeration pipe runs lengthways beneath the ridge of the pile. Individual piles hold a single large batch of material or a few batches of roughly the same recipe and age (e.g. within three days). Individual piles are practical where raw materials are available for composting at intervals rather than continuously.

As the pile does not receive additional turnings, the selection and initial mixing of raw materials are critical to avoiding poor air distribution and uneven composting. The pile also needs a good structure in order to maintain porosity throughout the entire composting period. This generally requires a stiff bulking agent such as straw or wood chips. Wood chips are often used for composting sewage sludge by this method. Because of their large size, wood chips pass through the process only partially composted. They are usually screened from the finished compost and reused as bulking agents for another two or three cycles. As straw decomposes during the composting period, a pile with straw as an amendment can lose structure gradually. This is compensated partially by the drying that takes place as composting proceeds. Other possible bulking agents and amendments for static pile composting include: recycled compost, peat moss, corn cobs, crop residues, bark, leaves, shellfish shells, waste paper, and shredded tyres. Uncomposted material such as shredded tyres and mollusc shells must be screened from the compost and reused. To obtain good air distribution, manure or sludge must be blended thoroughly with the bulking agent before the pile is established.

The required airflow rates and the choice of blowers and aeration pipe depend on how aeration is managed, i.e. how the blower is controlled. The blower can be run continuously or intermittently. In the latter case, the control mechanism can be a programmed time clock or a temperature sensor.

The airflow rates are based on the dry weight of the primary raw material, such as sludge or manure. They should take into account the presence of typical amendments such as wood chips, straw, and compost. In practice, it may be necessary to adjust the timer cycle, pile size, and blower to suit the specific conditions and materials.

For static pile composting, the air can be supplied in two ways: a suction system with the air drawn through the pile; or a pressure system with the blower pushing the air into the pile. Suction draws air into the pile from the outer surface and collects it in the aeration pipe. As the exhaust air is contained in the discharge pipe, it can be filtered easily if odours occur during the composting process.

With positive pressure aeration, the exhaust air leaves the compost pile over the entire pile surface. Therefore, it is difficult to collect the air for odour treatment. Where better odour control is desired, a thicker outer layer of compost can be used. Pressure aeration provides better airflow than suction aeration, largely because of the lack of an odour filter. The lower pressure loss results in greater airflow at the same blower power. Therefore, pressure systems can be more effective at cooling the pile and they are preferred where temperature control is the overriding concern.

In-vessel composting

In-vessel composting refers to a group of methods that confine the composting materials within a building, container or vessel (NRAES, 1992). In-vessel methods rely on a variety of forced aeration and mechanical turning techniques to accelerate the composting process. Many methods combine techniques from the wind-row and aerated pile methods in an attempt to overcome the deficiencies and exploit the attributes of each method.

There are a variety of in-vessel methods with different combinations of vessels, aeration devices, and turning mechanisms. The methods discussed here have either been used or proposed for farm composting.

Bin composting

Bin composting is perhaps the simplest in-vessel method. The materials are contained by walls and usually a roof. The bin may simply be wooden slatted walls (with or without a roof)

Plate 8
Bin composting
[NRAES-114, 1999; COURTESY: R. Rynk]

(Plate 8), a grain bin, or a bulk storage building. The buildings or bins allow higher stacking of materials and better use of floor space than free-standing piles. Bins can also eliminate weather problems, contain odours, and provide better temperature control.

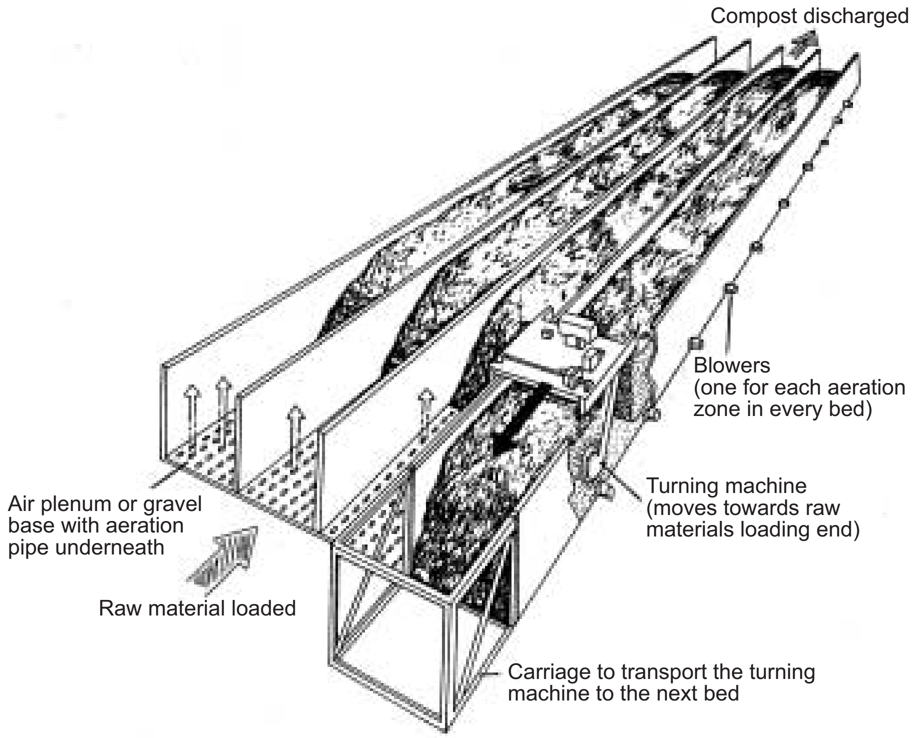
Bin composting methods operate in a similar way to the aerated static pile method. They include some means of forced aeration in the floor of the bin and little or no turning of the materials. Occasional remixing of material in the bins can invigorate the process. Where several bins are used, the composting materials can be moved periodically from one bin to the next in succession. Most of the principles and guidelines suggested for the aerated pile also apply to bin composting. One exception relates to relatively high bins. In this case, there is a greater degree of compaction and a greater depth of materials for air to pass through. Both factors increase resistance to airflow (pressure loss). A raw material with a stronger structure and/or a higher pressure blower may be required, compared to the aerated static pile method.

Passively aerated bin composting of municipal waste in Phnom Penh

A lack of proper waste management services causes health and environment problems. This is a serious urban issue in developing countries. There are various projects, mostly initiated by local non-governmental organizations (NGOs), to establish community-scale waste management facilities. The Waste Recycling Development Centre is run by the Community Sanitation and Recycling Organization (Web site: http://www.bigpond.com.kh/users/csaro/), a local NGO in Phnom Penh, Cambodia, and has a small-scale, passively aerated bin composting plant. Although this may not be 'on-farm' composting in a strict sense, the techniques are valid and affordable to on-farm production and, more importantly, this is a good example of waste composting that may be applicable particularly to peri-urban agriculture.

Compostable materials, such as kitchen waste, tree leaves, and coconut husks, are retrieved and sorted to achieve an effective C:N ratio and water content, and then shredded with a locally manufactured machine to accelerate composting before piling into a bin 2 m (width) × 2 m (length) × 1 m (height). Each bin is surrounded by walls on three sides. The walls are made of concrete blocks with holes. The floor is bedded with coconut shells to improve aeration in the lower part of the pile. There are also two sets of perforated plastic pipes, each consisting of one horizontal tube connected to two upright tubes. The pile collects heat quickly and the temperature rises to 70 °C. Water is added to maintain an adequate moisture content. The pile is normally turned one month later, but it is also turned at below 48 °C in order to boost aerobic decomposition. Composting is complete in about two months when the pile cools to below 27 °C. Finally, the compost is sieved, packed in 30–kg bags and sold.

Figure 4
Rectangular agitated bed composting system



Source: NRAES-54, 1992.

Rectangular agitated beds

The agitated bed system combines controlled aeration with periodic turning. The composting takes place between walls that form long, narrow channels referred to as beds (Figure 4). A rail or channel on top of each wall supports and guides a compost-turning machine.

A loader places raw materials at the front end of the bed. As the turning machine moves forward on the rails, it mixes the compost and discharges the compost behind itself. With each turning, the machine moves the compost a set distance toward the end of the bed. The turning machines work in a similar way to wind-row turners, using rotating paddles or flails to agitate the materials, break up clumps of particles, and maintain porosity. Some machines include a conveyor to move the compost. The machines work automatically without an operator and are controlled with limit switches.

Most commercial systems include a set of aeration pipes or an aeration plenum recessed in the floor of the bed and covered with a screen and/or gravel. Between turnings, aeration is supplied by blowers to aerate and cool the composting materials. As the materials along the length of the bed are at different stages of composting, the bed is divided into different aeration zones along its length. Several blowers are used per bed. Each blower supplies air to one zone of a bed and is controlled individually by a temperature sensor or time clock.

The capacity of the system is dependent on the number and size of the beds. The width of the beds in commercially available systems ranges from about 180 to 600 cm, and bed depths are between about 90 and 300 cm. The beds must conform to the size of the turning machine, and the walls must be especially straight. To protect equipment and control composting conditions, the beds are housed in a building or a greenhouse or, in warm climates, covered by a roof.

The length of a bed and frequency of turning determine the composting period. Where the machine moves the materials 300 cm at each turning and the bed is 30 m long, the composting period is ten days with daily turning. It increases to 20 days where turning occurs every other day. Suggested composting periods for commercial agitated bed systems range from two to four weeks, though a long curing period may be necessary.

Silos

Another in-vessel technique resembles a bottom-unloading silo. Each day an auger removes composted material from the bottom of the silo, and a mixture of raw materials is loaded at the top. The aeration system blows air up from the base of the silo through the composting materials. The exhaust air can be collected at the top of the silo for odour treatment. A typical composting time for this method might be 14 days, so one-fourteenth of the silo volume must be removed and replaced daily. After leaving the silo, the compost is cured, often in a second aerated silo. This system minimizes the area needed for composting because the materials are stacked vertically. However, the stacking also presents compaction, temperature control and airflow challenges. Because materials receive little mixing in the vessel, raw materials must be well mixed when loaded into the silo.

Rotating drums

This system uses a horizontal rotary drum to mix, aerate and move the material through the system. The drum is mounted on large bearings and turned through a bull gear. A drum about 3.35 m in diameter and 36.58 m long has a daily capacity of approximately 50 tonnes with a residence time of three days. In the drum, the composting process starts quickly; and the highly degradable, O-demanding materials are decomposed. Further decomposition of the material is necessary and is accomplished through a second stage of composting, usually in wind-rows or aerated static piles. In some commercial systems, the composting materials spend less than one day in the drum. In this case, the drum serves primarily as a mixing device.

Air is supplied through the discharge end and is incorporated into the material as it tumbles. The air moves in the opposite direction to the material. The compost near the discharge is cooled by the fresh air. In the middle, it receives the warmed air, which encourages the process; and the newly loaded material receives the warmest air to initiate the process.

The drum can be open or partitioned. An open drum moves all the material through continuously in the same sequence as it enters. The speed of rotation of the drum and the inclination of the axis of rotation determine the residence time. A partitioned drum can be used to manage the composting process more closely than the open drum. The drum is divided into two or three chambers by partitions. Each partition contains a transfer box equipped with an operable transfer door. At the end of each day's operation, the transfer door at the discharge end of the drum is opened and the compartment emptied. The other compartments are then opened and transferred in sequence, and finally a new batch is introduced into the first compartment. A sill in place at each of the transfer doors retains 15 percent of the previous charge to act as an inoculum for the succeeding batch. Upon discharge, the compost can go directly into a screen to remove oversized particles, which can be returned to the drum for further composting.

On a smaller scale, composting drums can be adapted from equipment such as concrete mixers, feed mixers, and old cement kilns. Although less sophisticated than commercial models, the functions are the same: mix, aerate, and ensure that the composting process starts rapidly.

Transportable containers

A different type of in-vessel system, relies on a transportable vessel and a central composting facility. A number of local farms participate and provide manure as a raw material. Each farm receives a transportable vessel, which resembles a solid waste roll-off container. In its base, the container has aeration pipes that are connected to a blower. At the farm, the manure and dry amendments are loaded daily into the container and aerated for several days until the container is picked up and delivered to the central facility to finish composting. When the composting container is picked up, the farm is provided with another empty container to continue the cycle. The farm supplies the manure and receives bulking agent, compost and/or revenue in return.

Chapter 4
Vermicomposting

The term vermicomposting means the use of earthworms (Plate 9) for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day, e.g. 1 kg of worms can consume 1 kg of residues every day. The excreta (castings) of the worms are rich in nitrate, available forms of P, K, Ca and Mg. The passage of soil through earthworms promotes the growth of bacteria and actinomycetes. Actinomycetes thrive in the presence of worms and their content in worm casts is more than six times that in the original soil.

Types of worms

A moist compost heap of 2.4 m by 1.2 m and 0.6 m high can support a population of more than 50 000 worms. The introduction of worms into a compost heap has been found to mix the materials, aerate the heap and hasten decomposition. Turning the heaps is not necessary where earthworms are present to do the mixing and aeration. The ideal environment for the worms is a shallow pit and the right sort of worm is necessary. *Lumbricus rubellus* (red worm) and *Eisenia foetida* are thermo-tolerant and so particularly useful. Field worms (*Allolobophora caliginosa*) and night crawlers (*Lumbricus terrestris*) attack organic matter from below but the latter do not thrive during active composting, being killed more easily than the others at high temperature.

European night crawlers *(Dendrabaena veneta* or *Eisenia hortensis)* are produced commercially and have been used successfully in most climates. These night crawlers grow to about 10–20 cm. The African night crawler (*Eudrilus eugeniae*), is a large, tropical worm species. It tolerates higher temperatures than *Eisenia foetida* does, provided there is ample humidity. However, it has a narrow temperature tolerance range, and it cannot survive at temperatures below 7 °C. Vermicomposting is in use in many countries. Experiences from selected countries are described as case studies.

Plate 9
Close-up of worm culture
[FAO/17449/ODOUL]

Case studies

Vermicomposting in the Philippines

The worms used in this study (FAO, 1980) were *Lumbricus rubellus* and/or *Perionyx excavator*. The worms were reared and multiplied from a commercially-obtained breeder stock in shallow wooden boxes stored in a shed. The boxes were approximately 45 cm × 60 cm × 20 cm and had drainage holes; they were stored on shelves in rows and tiers.

The bedding material comprised miscellaneous organic residues such as sawdust, cereal straw, rice husks, bagasse and cardboard, and was well moistened with water. The wet mixture was stored for about one month, being covered with a damp sack to minimize evaporation, and was mixed thoroughly several times. When fermentation was complete, chicken manure and green matter, such as ipil ipil leaves or water hyacinth, were added. The material was placed in the boxes. It was sufficiently loose for the worms to burrow and it was able to retain moisture. The proportions of the different materials varied according to the nature of the material, but the aim was to achieve a final protein content of about 15 percent. A pH value as near neutral as possible was necessary and the boxes were kept at temperatures between 20 and 27 °C (at higher temperatures, the worms aestivate; at lower temperatures, they hibernate).

Although the worms were able to eat the bedding material, the worms were fed regularly at this stage: every kilogram of worms received 1 kg of feed every 24 hours. For each 0.1 m^2 of surface area, 100 g of breeder worms were added to the boxes. The feedstuffs included chicken manure, ipil ipil, and vegetable wastes. At one farm, water hyacinth was grown specifically and used fresh (chopped up) as the sole source of feed. Some form of protection was required against predators (birds, ants, leeches, rats, frogs and centipedes).

Composting procedure

A series of pits (the number depending on the space available) were dug approximately 3 m × 4 m × 1 m deep, with sloping sides. Bamboo poles were laid in a parallel row on the pit floor and covered with a lattice of wood strips. This provided the necessary drainage as the worms could not have survived in a waterlogged environment.

The pits were lined with old feedstuff sacks to prevent the worms from escaping into the surrounding soil and yet permit drainage of excess water. The pits were then filled with rural organic residues such as straw and other crop residues, animal manure, green weeds, and leaves. The filled pits were covered loosely with soil and kept moist for a week or so. One or two spots on the heap were then well watered and worms from the breeding boxes were place on top. The worms burrowed down immediately into the damp soil.

In order to harvest the worms from the boxes, two-thirds of the box was emptied into a new box lined with banana leaf or old newspaper. The original box was then provided with fresh bedding material and those worms remaining multiplied again. The worms emptied from the box were picked out by hand for adding to the heap.

The compost pits were left for a period of two months; ideally such pits should be shaded from hot sunshine and kept moist. Within two months, about 10 kg of castings had been produced per kilogram of worms. The pits were then excavated to an extent of about two-thirds to three-quarters and the bulk of the worms removed by hand or by sieving. This left sufficient worms in the pit for further composting, and the pit was refilled with fresh organic residues. The compost was sun-dried and sieved to produce good quality material. A typical analysis was:

organic matter, 9.3 percent; N, 8.3 percent; P, 4.5 percent; K, 1.0 percent (water soluble); Ca, 0.4 percent; and Mg, 0.1 percent.

The excess worms harvested from the pits were then either used in other pits, sold to other farmers for the same purpose, used or sold as animal feed supplement, used or sold as fish food, or used in certain human food preparations.

Vermicomposting in Cuba

In Cuba, different methods are used for worm propagation and vermicomposting (Cracas, 2000).

Worm trough rows

The most common method uses cement troughs (60 cm × 180 cm) to raise worms and create worm compost. Because of the climate, they are watered by hand every day. In these beds, the only feedstock for the worms is manure. This manure is aged for about one week before being added to the trough. First, a layer of 7.5–10 cm of manure is placed in the empty trough, and then worms are added. As the worms consume the manure, more manure is layered on top, about every ten days, until the worm compost reaches to within about 5 cm of the top of the trough (about two months). Then the worms are separated from the compost and transferred to another trough.

Wind-rows

Another method of vermicomposting is wind-rows. Cow manure is piled about 90 cm across and 90 cm high. It is then seeded with worms. As the worms work their way through it, fresh manure is added to the end of the row, and the worms move forward. The rows are covered with fronds or palm leaves to keep them shaded and cool. Some of these rows have a drip system (a hose running alongside the row with holes in it) but most are watered by hand. Some of these rows are tens of metres in length. The compost is gathered from the opposite end once the worms have moved forward. It is then bagged and sold. Fresh manure, seeded with worms, begins the row and the process again. Some of the wind-rows have bricks running along their sides, but most are simply piles of manure without sides or protection. Manure is static composted for 30 days, then transferred to rows for worms to be added. After 90 days, the piles reach a height of about 90 cm. Wind-rows are also used to compost rice hulls and sugar cake (cake is what is left after sugar cane has been processed), but this too is mixed with animal manure. Food scraps are sometimes added to worm beds.

Vermiculture in India

This approach (Jambhhekar, 2002) uses the following materials: breeder worms, a wooden bed and organic wastes. The bed should be of the desired length and about 75 cm high × 120 cm wide. Worms should be applied for every part of waste. Other steps in the process are:

- Sieving and shredding – decomposition can be accelerated by shredding raw materials into small pieces.
- Blending – carbonaceous substances such as sawdust, paper and straw can be mixed with N-rich materials such as sewage sludge, biogas slurry and fish scraps to obtain a near

optimum C:N ratio. A varied mixture of substances produces good quality compost, rich in macronutrients and micronutrients.

- Half digestion – the raw materials should be kept in piles and the temperature allowed to reach 50–55 °C. The piles should remain at this temperature for seven to ten days.
- Maintaining moisture, temperature and pH – the optimum moisture level for maintaining aerobic conditions is 40–45 percent. Proper moisture and aeration can be maintained by mixing fibrous with N-rich materials. The temperature of the piles should be 28–30 °C. Higher or lower temperatures reduce the activity of microflora and earthworms. The height of the bed can help control the rise in temperature. The pH of the raw material should not exceed 6.5–7.

The compost is ready after about one month. It is black, granular, lightweight and humus-rich. In order to facilitate the separating of the worms from the compost, watering should cease two to three days before emptying the beds. This forces about 80 percent of the worms to the bottom of the bed. The remaining worms can be removed by hand. The vermicompost is then ready for application.

Some entrepreneurs have made modifications, e.g. making the floor leakproof, and providing a covered shade in order to ensure temperature regulation and protection against accumulation of excessive water in the rainy season. Although this adds to the cost, the improved efficiency of vermicomposting and faster rate of growth of earthworms more than offsets this additional cost.

The excess water, which may be leached along with the earthworms extracts, is also collected from the concrete flooring and recirculated. This ensures high N content in the finished product and also better quality because of the preserved worm extracts. The steps in this process are:

- Cattle dung is collected from cow shelters.
- The dung is kept for about 7–10 days to let it cool.
- Beds/rows of dung and crop residues/leaves, etc. are made about 1 m wide, 75 cm high and with a distance of 75 cm between two rows.
- In the beds/rows, crop waste such as leaves, straw etc. is layered alternatively with the dung to thus make a height of about 75 cm. The beds are kept as such for 4–5 days to cool.
- Water is sprinkled to let the compostable matter cool down.
- Earthworms are put on the top of the manure row/bed. About 1 kg worms in a metre-long manure row are inoculated.
- It is left undisturbed for 2–3 days after covering with banana leaves. Covering with jute bags or sacks is not recommended as it heats the manure bed.
- The bed is opened after 2–3 days. The upper portion of about 10 cm of manure is loosened with the help of a suitable hand tool.
- The bed is covered again. The worms feed on an upper bed of about 10 cm. This portion becomes vermicasted in about 7–10 days.
- This portion (vermicasted manure) is removed and collected near the bed. Another upper portion of 10 cm is loosened and covered again with the leaves.
- Moisture is maintained in the bed by regular sprinkling of water.
- The loosened portion of the manure is vermicasted in another 7–10 days and is removed again.

- Thus, in about 40 days, about 60 cm of the bed is converted into vermicompost and is collected on 3–4 occasions.
- The remaining bed of about 10 cm in height contains earthworm mixed manure.
- Fresh manure mixture/organic residues, etc. are again put on the residual bed containing earthworms of about 10 cm and the composting process is restarted.
- The manure collected from the bed is freed of worms through sieving. Uncomposted or foreign matter is also removed in this way.
- The screened manure is bagged and used or sold as required.

Enhancing vermicompost production

Vermicompost production using epigeic compost worms such as *Eisenia foetida*, *Lumbricus rubellus* and *Eudrilus eugeniae* can be enhanced effectively by supplementing the organic wastes used for vermicomposting with cow urine . Undiluted urine can be used for moistening organic wastes during the preliminary composting period (before the addition of worms.). After the initiation of worm activity, urine can be diluted with an equal quantity of water. No problems have been observed with daily use of diluted cow urine for moistening the vermicomposting bed. This simple technique can yield vermicompost with a higher N content. Moreover, worms have been found to become very active and vermicompost can be harvested at least 10 days early.

Integrating traditional composting and vermicomposting

Problems associated with traditional thermophilic composting relate to: long duration of the process, frequent turning of the material, material size reduction to enhance the surface area, loss of nutrients during the prolonged process, and the heterogeneous resultant product. However, the main advantage of thermophilic composting is that the temperatures reached during the process are high enough for an adequate pathogen kill.

In vermicomposting, the earthworms take over both the roles of turning and maintaining the material in an aerobic condition, thereby reducing the need for mechanical operations. In addition, the product (vermicompost) is homogenous. However, the major drawback of the vermicomposting process is that the temperature is not high enough for an acceptable pathogen kill. Whereas in traditional thermophilic composting the temperatures exceed 70 °C, the vermicomposting processes must be maintained at less than 35 °C.

A study has examined the possibility of integrating traditional thermophilic composting and vermicomposting (Ndegwa and Thompson, 2001). The work involved combining pertinent attributes from each of the two processes to enhance the overall process and improve the product qualities. The two approaches investigated in the study related to: (i) pre-composting followed by vermicomposting; and (ii) pre-vermicomposting followed by composting. The duration of each of the combined operations viz. composting and vermicomposting was four weeks. A comparison was made with vermicomposting alone (duration: 56 days). The results indicated that the combination of the two processes shortened the stabilization time and improved product quality. Furthermore, the resultant product was more stable and consistent, had less potential impact on the environment, and met pathogen reduction requirements.

References

Community Sanitation and Recycle Organization (CSARO). Web site: http://www.bigpond.com.kh/users/csaro/

Cracas, P. 2000. Vermicomposting Cuban style. *Worm Dig. Iss.*, 25 – online articles.

FAO. 1980. *A manual of rural composting*. FAO/UNDP Regional Project RAS/75/004 Field Document No. 15. Rome.

FAO. 2002. *Biofertilizer production plant, Myanmar (FAO/UNDP Project)*, by H. Hiraoka. Back to Office Report. Bangkok, FAO–RAP.

Indian Agricultural Research Institute (IARI). 1989. *Biofertilizers*. New Delhi, Division of Microbiology.

Jambhhekar, H. 2002. *Vermiculture in India – online training material*. Pune, India, Maharashtra, Agricultural Bioteks.

Manickam, T.S. 1967. *Chemistry of fertilizers and manures*. Coimbatore, India, Division of Soil Science and Agricultural Chemistry, Agricultural Research Institute.

Natural Resource, Agriculture, and Engineering Service (NRAES). 1992. *On-farm composting*, edited by R. Rynk. Ithaca, USA, NRAES Cooperative Extension.

Ndegwa, P.M. & Thompson, S.A. 2001. Integrating composting and vermicomposting in the treatment and bioconversion of biosolids. *Biores. Tech*., 76(2): 107–112.

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G. & Giller, K.E. 2001. Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. *Ag. Ecosys. Env.*, 83: 27–42.

Raabe, R.D. 2001. *The rapid composting method*. University of California, US, Co-operative Extension, Division of Agriculture and Natural Resources.

Ramasami, S. 1975. *Processing of bones into bonemeal and its effect on plant growth*. New Delhi, Indian Agricultural Research Institute. (PhD thesis)

Richard, T. 1996. The effect of lignin on biodegradability. *In: Cornell composting*. (available at http://www.cfe.cornell.edu/compost/calc/lignin.html

Schorth, G. 2003. Decomposition and nutrient supply from biomass. *In* G. Schorth & F.L. Sinclari, eds. *Trees, crops and soil fertility: concepts and research methods*. CABI Publishing, ISBN–0851995934.

Smith, R.C. 1995. *Composting practices*. NDSU Extension Service, North Dakota State University of Agriculture and Applied Science, and USDA.

Tamilnadu Agricultural University (TNAU). 1999. *Crop production guide*. Coimbatore, India.

Virginia, C.C. 1997. *Rapid composting technology in Philippines: its role in producing good quality organic fertilizers*. Extension Bulletin. Taiwan Province of China, FFTC.

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On-farm composting methods

Soil productivity and environmental concerns have revived global interest in organic recycling practices such as composting. Composting is an attractive proposition for turning on-farm organic waste material into a valuable farm resource. A range of approaches to composting for different situations have been used. However, the information on recently evolved quick composting methodologies, especially those suited to small farmers, remains scattered and needs consolidation. The publication presents an overview of on-farm composting methodologies with special emphasis on rapid composting processes, and is intended to promote their wide-scale adoption with the ultimate objectives of improving soil productivity in developing countries and protecting the environment from degradation.

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