VERMICOMPOSTING

Introduction

Vermiculture or vermicomposting is derived from the Latin term vermis, meaning worms. Vermicompsting is essentially the consumption of organic material by earthworms. This speeds up the process of decomposition and provides a nutrient-rich end product, called vermicompost, in the form of ‘worm castings’.

For centuries, earthworms have been used for centuries as a means of decomposing wastes and improving soil structure. Increasing numbers of businesses worldwide are successfully employing vermiculture technology and marketing vermicompost as an excellent soil conditioner, to farmers and gardeners. The breeding and propagation of earthworms and the use of its castings has become an important method of waste recycling throughout the world. It is common to use earthworms on industrial scales to aerate, sanitise and deodorise types of contaminated waste sludge. For instance, Japan imports millions of tonnes of earthworms per annum for waste conversion. Worms are odourless and free from disease. Vermiculture looks set to emerge as a significant waste management technology.

Essentially, earthworms function as natural bioreactors. The technique yields organic fertilisers, permits safe disposal of certain organic wastes and reduces the requirement for landfill.

Vermicompsting can be conducted all year-round, providing environmental conditions remain within acceptable limits. For increased efficiency, care should be taken to ensure that organic feedstock and conditions allow worms to reproduce successfully and to withstand moisture and climatic fluctuations. Given suitable conditions, vermicomposting appears to provide a relatively straightforward solution to the management of compostable organic wastes.

Worm Species and Reproduction

Two species of red earthworms have consistently been used for commercial composting or worm farming, due to their relatively high tolerance of environmental variations:

a) *Eisenia foetida* The Red Wiggler;
b) *Lumbricus rebellus* The Red Worm.

Earthworms are hermaphroditic - that is, each worm is both male and female and each can produce eggs and fertilise the eggs produced by another worm. Under perfect conditions a mature breeder will produce an egg capsule every 7 to 10 days, each containing over 1 dozen hatchlings. Development takes 14-21 days and, once hatched, the newly-emerged worms reach maturity in approximately four to six weeks, meaning that the worm population may double each month.

In theory, 1 kilo of worms can increase to 1,000 kilos (approximately one million worms) in a year. However, in working conditions 1 kilo may produce a surplus of 10 kilos in one year, because hatchlings and capsules (cocoons or eggs) are usually lost when the vermicompost is harvested. This rapid breeding rate means the worm population easily adjusts to environmental conditions, feed supply and the proportion of worm casts to feed and bedding.

Population Controls

Three basic conditions control the size of a worm population:

1. Food availability
2 Space requirements
3. Fouling of their environment

When food and waste is regularly fed to worms in a limited space, the worms and associated organisms break down this waste, absorbing the nutrients they require and excreting the rest. As the worms reproduce competition for the available food increases. The density of the worms may exceed that favourable for cocoon production, resulting in slower reproduction. In order to for worm populations to increase, they must be provided with increasing amounts of food, space and fresh bedding.

Additionally, all the worms excrete castings, which have been shown to be toxic to members of their own species. As more of the bedding is converted to castings, worms will migrate, if possible, to areas with a higher proportion of feedstock and a lower proportion of casts. If conditions deteriorate, worm's numbers may drop.

This is an important consideration for municipal-scale composting, as very large quantities of worms will need to be maintained, depending on the quantity of organic waste arisings and desired rate of throughput. As previously highlighted, worm populations may increase rapidly from a relatively small initial number. Once the required number of worms is present, they should be regarded as a valuable asset, and viewed in terms of replacement costs. In order to maintain worm numbers it may be necessary to harvest a slightly lower grade of vermicompost, before the proportion of castings reaches toxic levels. Worms separated from the casts are then used to expand the system. Some authorities believe that, under ideal conditions, worms may live as long as ten years.

Castings

When expelled, worm casts consist of granules, surrounded by a mucus, which hardens upon exposure to air. When granular castings are mixed into garden or houseplant soils there is a slow "time release" of nutrients. However, the hardened particles of mucus do not readily break down. Instead, they serve to break up soils, providing aeration and improving drainage. Worm casts therefore provide an organic soil conditioner as well as a natural fertiliser.

Nutrient Content

Vermicompost consists mostly of worm casts plus some decayed organic matter. In ideal conditions worms may consume their own weight of organic matter each day. One tonne of worms may therefore process one tonne of organic waste per day. Vermicompost is organic, non-burning and rich in nutrients. Worm casts are suitable for a wide range of horticultural uses. Vermicompost contains eight times as many microorganisms as their feed, which promotes healthy plant growth.

When compared with soil, worm casts also contain:

5	times more nitrogen;
7	times more phosphorus;
1.5	times the calcium;
11	times more potassium;
3	times more exchangeable magnesium.

The casts are also rich in humic acids, which condition the soil, have a perfect pH balance, and have plant growth factors similar to those found in seaweed.

Bedding Materials

Earthworms require adequate temperature, moisture and ventilation. Bedding retains moisture and provides a medium in which the worms can work and in which waste organic material can be buried. It should be light enough to allow air exchange and should not be packed down. Worms actually consume bedding as well as kitchen vegetable wastes. Bedding can be made of shredded newspaper, shredded corrugated cardboard, peat moss, or leaf mould. Bedding must be dampened with water before adding to the bin. Never use water from a water softener, as the salt will kill the worms.

Suitable bedding materials include:

- Shredded or mulched paper such as newspaper (non coloured)
- cardboard
- shredded fall leaves
- chopped up straw
- sawdust
- dried grass clippings
- peat moss
- Fibrous garden matter such as cornhusks

The bedding material should be varied in order to provide a range of nutrients for the earthworms and to produce richer compost.

Temperature

The optimum temperature for earthworms is between 55-77 degrees. To remain active during winter, the system should be maintained at a temperature above 10°C. The system should not be allowed to freeze. In large-scale operations, temperatures at the centre of the decomposing material should remain sufficiently high during winter months to sustain the earthworm population without the need for additional heat.

Sunlight

Earthworms have an aversion to bright lights. One hour's exposure to ultraviolet rays from strong sunlight causes partial-to-complete paralysis and several hours are fatal. A worm breathes when oxygen from the air or water passes through its moist skin into the blood capillaries. If the body covering dries up, the worm suffocates.

Environmental Factors

The three most important environmental factors are:

Temperature,
Moisture and
Ventilation.

All worms need moisture. The bedding should have moisture content similar to a wrung-out sponge. Worms also need oxygen. It is important to allow air to circulate around the bin by not covering the air holes.

Worm bins can be used indoors all year round, and outdoors during the winter months. Outdoor bins should be kept out of the sun and rain. The literature on vermicomposting suggests that if temperatures drop below 10°C (50 degrees f), bins should be moved indoors.

Feedstocks

Red earthworms will eat most forms of kitchen vegetable or fruit waste, in addition to tealeaves, tea bags, coffee grounds, paper and shredded green garden waste. Materials to be avoided in significant quantities include meats, dairy products, eggs, oily foods, salt and vinegar.

Red earthworms will eat their own weight every day. This weight includes their bedding, so every kilo of worms or part thereof, may be fed 50% to 100% of their combined weight in food or green waste.

Separation Techniques

Once vermicomposted, the volume of material will be much reduced, possibly down to 10% of its original volume. The finished material will brown and earthy-like, and the original bedding will no longer recognisable. If only the worm casts are required as a fertiliser, any of the following methods are appropriate. In order to separate and retain worms as well as casts, the light separation method or a wire mesh screen will be required. The methods described are best suited to smaller-scale containerised systems or pilot operations designed to breed initial worm populations. Once the system is expanded, it will be necessary to use a commercial-scale mesh screener.

Light Separation

This method utilises worms' sensitivity to light and tendency to burrow beneath the surface in order to escape light sources. The finished material may be removed and spread onto a surface or else left in-situ, but should be exposed to a light source. The worms will quickly burrow downwards, allowing the surface material to be removed. After repeating this operation, a thin layer of material remains, containing all of the worms. This should be added to the new bedding with a fresh supply of feed. This leaves a harvest of worm castings and un-hatched capsules. These capsules will be lost, as the hatchlings will not survive in garden soil, but the remaining worms quickly replace them. The castings should be stored for a week or two before use as a fertiliser.

Sideways Separation

The finished material is moved to one side, whilst fresh bedding mixed with organic waste is placed alongside. During the following 7 to 14 days the worms will migrate from the finished vermicompost into the fresh bedding. The advantage of this method is that it allows the capsules to hatch in the meantime and most will also move across.

Vertical Separation

A nylon mesh screen slightly larger than the surface area of the container is placed onto the surface of the vermicompost. The screen should be large enough to flatten up the sides of the container overlap at the top. The container is filled with fresh bedding on top of the screen and fed with organic waste. The worms will migrate up through the screen into the new bedding as the food source below is depleted.

When the upper part is ready for harvesting, the screen, and the finished material containing the worms is lifted from the container. The remaining material in the lower part of the container will have a very high concentration of worm castings and few if any worms, hatchlings or capsules. Once this is removed, the worm-filled material that was on top of the screen is placed into the bottom of the container with fresh bedding on top of the screen.

Gradual Transfer

This simple method produces castings, but no extra worms. Continue feeding kitchen scraps into the container for up to four months. A second container should be started and primed with fresh bedding and a supply of worms from the first box. The first container continues until the second is full, by which time the first container will contain a very high proportion of fine castings, but very surviving few worms. To ensure there are enough worms for both containers, the second can be prepared about a month earlier, adding some worms to it every time the first container is fed.

Screening

The vermicompost might require post-screening, especially if coarse green waste was incorporated into the bedding, as this takes longer to break down. This may be carried out manually on a pilot scale, but is identical to the screening and separation operation carried out using a commercial, rotating screener. The worms are separated effectively from finished vermicompost, though capsules and hatchlings are lost.

Information regarding municipal-scale vermiculture is relatively scarce, as the technique has more usually been employed on smaller scales, or has been combined with the rearing of worms for the angling market. In contrast to '*unassisted*' windrow composting, vermiculture has several distinct applications, with the potential to produce different grades of end product, depending on volume or time constraints:

1. The complete processing of organic wastes to produce top-grade vermicompost. This method produces the highest-grade end product, in the form of worm casts. These typically contain much higher concentrations of vital nutrients than standard composted material. Worm casts tend to be used as a high quality (and high value) soil conditioner within the horticultural sector, rather than as bulk compost or plant bedding material.

2. The partial processing of organic material, in order to accelerate the composting process or to provide a product of higher quality than standard compost.

3. Elimination of nuisance odours associated with the decay of organic matter, such as in forms of open air composting, which do not employ sealed 'in-vessel' equipment.

4. The energy requirements of vermicomposting are very small compared to the existing waste disposal systems and processing costs are negligible.

5. **The breeding of worms. Although this is not of primary concern for a municipal composting installation, such a facility would require very large numbers of worms in order to operate satisfactorily. The maintenance and increase of worm numbers is therefore necessary, in order to increase initial worm numbers as the facility expands.**

Continuous Flow Systems

The continuous flow system was developed by Dr. Clive Edwards at the Rothamstead Agricultural Research Station. These systems are quickly gaining popularity and have been adopted by many mid-scale operations. The efficiency savings offered by their continuous flow design increases with the amount of material processed. This system design is now almost ubiquitous in commercial mid to large-scale vermicomposting systems. Each of these systems uses a relatively deep top-fed container, in which the composting mass sits upon a raised floor made from a widely spaced wire mesh. Worms are added to the system and food waste is added gradually, layered with bedding material. The system is continually fed until the bin is nearly full. The worms generally move upward through the feedstock / bedding layers and vermicompost is harvested from below by scraping or cutting a thin layer of finished material from just above the grill using a rake or a manually or hydraulically-operated blade.

Continuous flow systems offer several advantages to medium to large-scale composting operations. They are relatively straightforward to construct and operate. They are labour-efficient in terms of operation and harvesting finished material. They avoid the need for expensive equipment associated with technical 'in-vessel' systems and the turning and screening of windrowed material. It should be noted that, despite the recent and increasing interest in this design, windrows are still the most common large-scale vermicomposting system in use. Continuous flow vermicomposting designs are arguably the most efficient systems available, in terms of time and labour savings. However, regardless of efficiency or ease of operation, there is no design that eliminates the need for careful monitoring and good system management, which may require considerable initial experimentation and familiarisation.

Maintaining Continuous Flow

Continuous flow vermicomposting systems are becoming increasingly popular. They provide an ongoing flow of vermicompost that is easily removed from the system without disrupting the worm activity or requiring complex or time-consuming harvesting methods. Because of their operating efficiency, these system designs are becoming almost as popular as windrows for large-scale applications. However, like all vermicomposting systems, the continuous flow model poses several challenges.

In order to simplify some of the technical terminology, the worms most often used in vermicomposting are usually referred to as "surface feeders." They are generally presumed to only be active at or just below the surface. However, this is not always the case.

Earthworms are oxygen breathing, moisture-loving animals that require organic material to be bacterially active before they eat it. In their natural environment, this is usually top few inches of soil or surface organic litter, such as leaves. In any system with a free flow of oxygen, monitored moisture level and abundant supply of decomposing organic material, earthworms may spread throughout the material unless the system is carefully managed. Earthworms may therefore be found anywhere within the continuous flow systems which meets their requirements.

Feeding Rates

The precise loading rate (at which raw feedstock can be added to a worm bed to encourage the worms to concentrate at or near the surface) will vary depending on the feedstock being used, temperature, moisture levels and the density of the worm population. Proper loading rates require that new feedstock is not added until the majority of the previously added feedstock has been decomposed.

Adding new feedstock too early means there can lead to a build-up of unprocessed material within lower layers. There will therefore be sufficient available food deeper within the container, instead of being concentrated immediately below the surface. The worms will then spread into all the available food areas. Worm movement in the lower levels of a flow-through system often causes vermicompost to drop through the mesh floor before it has been sufficiently decomposed. Also, when the system is harvested, worms remaining low in the material will fall through with the vermicompost and will either need to be separated using labour-intensive screening methods, or will be lost to the system.

Most operators of continuous flow systems find that frequent additions of thin layers of feedstock (1"-2" deep spread across the surface) produce the best results. Feedstock is sometimes mixed with bulking agents like compost, shredded leaves, cardboard, paper or straw, or covered with an equally thin layer of these materials. Paper products are a preferred feedstock for earthworms, as they provide an easily accessible and digestible form of carbon.

Excessive Heating

Another of the challenges to any vermicomposting system, irrespective of size, is the potential for heating in the feedstock. Bacteria are the primary decomposers of raw organic matter and in an oxygen rich system, water, carbon dioxide and heat are produced as a result of microbial activity. When raw material is added to the system, particularly in large volumes, the mass can support the activity of billions of bacteria. Bacterial activity can produce significant amounts of heat, which may be trapped within the system. Even a small volume of raw material can result in heating if it contains sufficient energy to support high levels of bacterial activity. This potential for heating complicates the assessment system loading rates.

It should be recognised that a worm bed may contain thousands of different species of invertebrates and microorganisms, all of which play a vital role within the vermiculture ecosystem. The loading rate cannot therefore be based solely on the needs or capacity of a single organism in that system. Bacterial activity may have as much impact as the worm activity, as bacteria will have access to the feedstock first. Overfeeding (in relation to the design capacity, the type of feedstock and/or the level of system activity) may generate sufficient heat to deter worm activity. Unless design modifications can be made, such as installing fans to remove excess heat, the loading rate will need to be decreased to a point where heating is not a problem, even if that means feeding less material than the worms are capable of processing.

Pre-composting

Pre-composting the feedstock decreases the amount of energy contained within the material, so that heating doesn't take occur within the worm system. Feedstock which are pre-composted for 10-14 days retain sufficient nutrition for the worms, but not so much energy that they are able to generate heat.

One of the advantages to the continuous flow design is in the ease with which a continuous supply of vermicompost can be removed from the system. However, harvesting of the finished material should not begin until the system is nearly full of material. Many operators have found that, along with appropriate loading rates, a minimum depth of material in the system of between 12"-18" will help to ensure that few, if any, worms will be low in the bed and drop through, or fall out with the harvested vermicompost. Once fully charged, vermicompost then needs to be removed at a rate that maintains a relatively constant level of material in the system.

Continuous Flow System: Oregon Soil Corporation

In 1991, Oregon Soil Corporation, built a vermicomposting 'worm reactor', based on the continuous flow design developed by Dr. Clive Edwards during the 1980s. The system was designed to process large volumes of organic material and produce large volumes of vermicompost under the management of a single operator.

Feedstock consists of screened food waste, which is mixed with compost in order to absorb excess moisture and ensure good porosity, then fed into the system the same day. The is housed in an unheated greenhouse to protect it from the almost constant winter rains of the Pacific Northwest. Temperature is maintained by the microbial activity in the decomposing feedstock. Keeping large-scale systems cool enough for worm activity was found to be more of a challenge than keeping them warm, requiring that the system's loading rate is carefully monitored to prevent overheating. Moisture content is monitored closely and water added as necessary. As the feedstock is high in moisture, varying volumes of compost are added to each load of feedstock to balance the moisture level for optimum worm activity.

The worm reactor is a modular unit approximately 40" high and eight feet wide, with a working bed depth of approximately 24". Due to it's modular design it can be built to almost any length. The Oregon system is 125 feet long with a surface area of 1000 square feet. The base is constructed of wire mesh, to enable the finished vermicompost to fall through. The system was initially set up with a layer of newspaper above the mesh, which prevented the fresh material from falling through. Finished vermicompost tends to hold together, even when resting on the wide wire mesh, and does not readily fall through the openings. The material needs to be disturbed to enable harvesting.

To enable one person to feed the system efficiently, it uses an automated overhead gantry to deliver a consistent layer of feedstock to the bedding surface. At peak operation the worm reactor can process approximately 6000 pounds of organic material per day, feeding approximately 6000-7000 pounds of worms. The worm reactor uses an automated harvesting system to remove finished vermicompost from beneath the table. A breaker bar dragged across the wire floor dislodges a thin layer of vermicompost, which falls through the wide mesh. A series of automated paddles are then engaged to scrape the vermicompost from under the table so that the operator can shovel it into a pile for drying. At peak operation Holcombe's system produces approximately two to three tons (five to seven yards) of vermicompost per day.

Vermitech 200

The Medical University of South Carolina uses a *Vermitech* system, measuring 18' long by 7' wide, to process approximately 200 pounds of cafeteria food waste each day. Instead of a lid, the system has a series of curved bars spanning the width of the bin. When temperatures are cool, these support a thick cover. The composting chamber consists of two eight-foot sections. An air conditioner and hydraulic equipment occupy the last two-foot section. A Vermitech shredder, with a conveyor belt attached, delivers feedstock to the bin.

Feedstock is combined with cardboard, shredded and spread onto the surface of the bedding. Every 2 or 4 weeks the hydraulic system removes the bottom layer of castings, which are used by the grounds department. The system has a payback time of three years.

For their newest system, MUSC constructed a foundation, consisting of an 18' x 24' sloping concrete pad with a drain. The floor is coated with acrylic so that castings can be cleaned up easily. The system also incorporated electricity, water and fans to control airflow. Start-up costs, including the building and supplies, were $54,000.

Vermitech 200 Feedstock

Initially MUSC used newspaper as a carbon-rich portion of their feedstock, alternating between shredded newspaper and food waste, then raking out the pile deposited in the bin. This sometimes left larger, dry pieces of newspaper intact. They then used only shredded food waste, which showed an improvement. However, excessive moisture caused worms to migrate out of the system. It has been found that cardboard works best as a carbon source. The system requires one and a half hours of maintenance each day.

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Evolve Composting Ltd.

Evolve Composting operates a 60 acre vermicomposting site in Newtown, Powys. The site has the capacity to process 60,000 tonnes of material per year. Opportunities are being assessed to increase the amount of material processed to 20,000 tonnes. The company breeds worms for sale to the angling industry, in addition to producing high grade soil conditioner , in the form of worm casts. This end product, marketed as 'Black Gold', currently has a commercial value of approximately £1 per kilo.

Waste material is piled into open windrows and also fed into covered, ground-level beds. Depending on the mix and nature of incoming waste, materials such as coarser, woody wastes may be composted in windrows, as may not be suitable for vermicomposting, even after mixing with other feedstocks.

Evolve Composting provides advice on vermicomposting and is involved in the distribution of small-scale vermicomposting containers to local schools and businesses. The company does not currently use a containerised or continuous flow system in its on-site operation. Material is fed into the ground-level worm beds until the composting and feeding reaches the capacity of the beds. This may take many months, after which the beds must be cleared out. The process is labour-intensive, and involves the screening and separation techniques described previously. A small revolving screener is currently employed to separate the worms from the finished casts. These worms are then sold to customers or used to re-stock the next composting beds.

The company currently receives green waste under an agreement with the local authority and producers of green waste. It also receives other feedstocks in the form of industrial waste products such as tea, and receives paper waste from a local paper mill.

Overall, the process is simple, reliable and yields a product with potentially high added value. Effective vermicomposting relies on a suitable mix of feedstocks, not solely green garden wastes. The results of the current waste analysis exercise may provide information on the likely arisings of other suitable feedstocks. Evolve Composting is able to advise on site requirements and is seeking partnership opportunities to manage municipal vermicomposting operations.

Limitations to Vermiconposting

Pathogens

Food waste presents particular challenges to operators of composting facilities. Research is ongoing to obtain definitive information on the removal of pathogenic bacteria during vermicomposting. Pathogens are eliminated at various temperatures. Whilst some may be reliably eliminated at lower temperatures, the removal of others may require temperatures too great to sustain earthworms. In contrast, some sources claim that one of the great benefits of vermicomposting is that disease pathogens are reliably eliminated within the worms' gut**.**

Mid-scale vermiculture systems are not the only options available for the on-site management of waste organic materials. Whilst vermiculture systems have significant potential for on-site application, even with specialised management, they cannot effectively process meat, seafood and dairy wastes.

This may have implications for local authorities charged with meeting the Assembly's future composting targets which, it is suggested, will require the collection of domestic and commercial kitchen waste.

Particle size reduction technology

The performance of on-site vermiculture- or composting-based systems will increase significantly from size reduction of feedstocks and blending with carbon-rich bulking agents. Shredding technology that can process the size-range of green waste likely to be encountered within a municipal context may prove cost prohibitive for the majority of applications. (Costings: *Ron Prosser, Cardiff Wood Waste)*
The literature suggests the possibility of the co-operative development of very large-scale vermiculture operations.

Comparison: Vermiculture, Lime Stabilisation and Co-Composting.

It is assumed that the operating costs are similar given the handling and mixing requirements of three systems. Given equal operating costs, very large-scale vermiculture has some distinct advantages:

- The process is odourless
- The end product vermicast is odourless, smelling like fresh soil.
- Vermicast has a high market value as a fertiliser or soil conditioner. Green waste is converted into an enhanced, value-added product, compared with standard compost.
- The market for the end product has not been saturated.
- Other organic wastes such as cardboard, vegetable dirty paper and commercial food waste may be incorporated into the blend, subject to regulatory guidance.
- Vermicast is easily transported. It can be bagged, or shipped in bulk without affecting the product.
- The small quantity of leachate produced is easily contained, and provides a valuable nutrient source to be re-fed into the system.
- A market may even be developed for using the worm leachate as a liquid fertilizer.
- It is claimed that as the process is pollution free it can be installed within the precinct of an existing treatment plant, or even in urban areas, reducing the cost of transportation of sludge.

The Commercial Viability of Very Large Scale Vermiculture

Very large-scale vermiculture is a capital-intensive activity. On a stand-alone basis, a facility the size of Redland provides an investment that yields a superior return to most infrastructure projects. The rate of return is determined by:

The initial capital investment.

The operating costs of the worm farm - reduced by technical innovation.

The fee charged to the local council - governed by competitive tender.

The return from the sale of the compost / wormcast fertiliser.

Reduced landfill requirements

Reduced purchases of topsoil for municipal parks or capping for landfill sites.

The Recycled Organics Unit (New South Wales) estimates that initial capital investment will be in the order of £1.0m – £1.1m for a facility with the capacity to process 20,000 m³ of waste each year.

It should be noted that this estimate is subject to considerable uncertainty, due to factors such as the effects of site variations upon construction costs. To date, it has not been possible to establish a reliable conversion rate between initial weight and expected volume for the green waste delivered to Cardiff Wood Waste. The waste is expected to reduce in *volume* by between 40% and 60%, once shredded, and to possibly reduce in *weight* by a similar percentage, due to gradual loss of its initial moisture content. This conversion factor (0.4 to 0.60) equates reasonably well with data from the Recycled Organics Unit, which estimates that an installation processing 20,000 m³ of waste will produce approximately 7,000 m³ of wormcast – a (volume) conversion factor of 0.35. Based on the figures produced by the Recycled Organics Unit, this volume of finished wormcast would be expected to have a wholesale value of £600,000. However, this value appears overly optimistic, and includes no detailed analysis of the quality or consistency of vermicompost produced. UK market conditions may also mean that a significantly different value might be realised for the product in this country. Using a low weight conversion factor of 10:1 for the weight of waste to end-product, 1,000 tonnes of green waste would produce 100 tonnes of worm casts. Evolve Composting currently realises approximately £1 per kilo for its bagged worm casts, which are marketed under the name 'Black Gold'. This would give a potential value of £100,000. Although the poor current development within the UK of markets for high value compost may be seen as an opportunity, it should be re-emphasised that commercial returns are very difficult to predict for compost products. Commercial prices may decline with the widespread introduction of municipal-scale composting.

Irrespective of commercial value, vermicomposting may provide a viable method of dealing with a proportion of municipal scale waste. The process meets, or exceeds all regulatory requirements, although the Assembly has yet to specifically advise on a preferred option for composting food waste, which may contain animal pathogens. The vermicast end product is superior to other re-use products, providing greater benefits, and hence value, to the agricultural consumer. The literature suggests that a co-operative partnership may be required between waste authorities considering the introduction of very large-scale vermiculture, but that this can turn the cost of waste disposal into a profit .

Composting Meat and Poultry Waste

The National Assembly for Wales does not yet sanction composting in relation to waste meat products, due to concerns regarding the limitations of composting methods to successfully eliminate pathogens. Irrespective of public health concerns particular to the UK, composting or vermicomposting does not appear to be a practicable solution to the management of waste meat products: Research conducted by the Recycled Organics Unit indicates that meat and poultry are difficult to process in vermiculture systems. Trials using different feedstocks showed that meat and poultry feedstock had to be significantly diluted with cardboard in order to achieve even a low rate of processing, which resulted in a build-up of non-processed feedstock (primarily cardboard). Continued monitoring may therefore be required, in order to ensure that households comply with the requirement to only include non-cooked vegetable matter, as even a relatively small level of contamination may reduce the efficiency of the system.

vermicomposting: Troubleshooting

When carried out correctly, vermicomposting does not produce offensive odours or attract flies. The best approach is prevention, but if smells occur, there are a number of possible causes and steps to remedy the problem.

1. The system can start to smell if it becomes overloaded, as it will contain more feedstock than the worms can process.

2. The bedding is too wet and compacted. Solution: (a) gently stir the entire contents to allow more air in and stop adding food waste for a week or so. Make sure that your food waste is still buried. (b) The lid can be removed or left slightly ajar to allow the contents to dry out.

3. The vermicompost has become too acidic. Solution: Add some calcium carbonate and cut down on the amount of citrus peel and other acidic food waste.

Flies and smells

Burying food waste just below the surface will discourage flies. Fruit flies within the system do no harm, but large numbers are an indication of overfeeding. The loading rate should be reduced and the surface should be covered with a damp newspaper.

The bin can also have an influx of soldier fly maggots. These can be up to an inch long, and are much larger than Vinegar fly larvae. The maggots assist the composting process, but can be removed by mixing in additional bedding and lime, as above. Alternatively, place bread soaked in milk on the surface. After several days, it will become infested with larvae and can be removed.

Stop feeding the worms, add more dry bedding, a small amount of lime, and stir the bin with the hand cultivator (hand-fork). Repeat until the smell diminishes.

Keep a tight lid on any container used to store waste before adding it to the vermicomposter. This will prevent flies from laying eggs in the scraps.

- General rule of thumb - 1 Kg of worms eats approx. 1/2 Kg of food waste per day.

- Worm bins should not be exposed to extreme temperatures.

- Because of the presence of harmful pathogens in faeces, the addition of pet wastes or biodegradable diapers to vermiculture systems bins is not recommended, unless a dedicated unit is specifically designed for such materials.

- Redworms are hermaphroditic, and will produce an egg capsule every 14-21 days, each containing over 1 dozen hatchlings.

- Composting worms prefer cool, damp and dark conditions, and will breed optimally when these conditions are maintained. They will tolerate temperatures from 40 F to 80 F, but in northern climates they should be brought inside when the temperature drops towards freezing.

- You may use grass clippings, shredded cardboard or newspaper, and coir (coconut husks) as a source of bedding for worm bins. Certain inks and dyes may alter the pH levels within the system.

- A small quantity of pulverised dolomite (limestone) to help buffer the pH towards worm-favourable neutral levels and away from acidic conditions.