Organic Matter and Frass Fertilizer Processing Methods

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You would likely have heard about insect frass, but did you know that this mix of insect excrement, gastric waste, exoskeleton shedding, and uneaten feed contains beneficial amounts of nitrogen, potassium and phosphorous (Chavez-Rico et. al., 2022)? These minerals can then be further processed and used as a natural fertilizer for plants! Insect frass is a popular and effective soil fertilizer widely used in the agriculture and horticulture industries, as farmers and horticulturists alike seek to move away from artificial, chemical alternatives. Frass processing methods such as composting and fermentation are then further used to enhance the performance of these natural fertilizers – with each of them presenting their own unique challenges.

In this article, we will be detailing and comparing the two frass processing methods of composting and fermentation. We will explore how these processes aid in enhancing the performance of insect frass, and further elaborate on how composting and fermentation are affected by various factors. Finally, we will also be sharing about the application of such methods to Black Soldier Fly (BSF) frass.

Composting

You might have seen people disposing their food waste into a giant bin in their backyard, where it subsequently turns into dark, brown, soil-like crumbs in a matter of months. That is known as the process of composting – whereby organic (natural) materials are subject to controlled, moist, self-heated conditions. Composting can be carried out in aerobic (with oxygen) or anaerobic (without oxygen) conditions.

The process of composting for natural fertilizer production helps make soil more fertile, increases the water retention of the soil, and improves nutrient delivery to plants (UNEP, 2021). Using compost as a natural fertilizer is also a more sustainable alternative to inorganic, chemical fertilizers. The latter is known to be unsustainable as they are made from non-renewable resources, highly polluting when washed off into water bodies – they cause algal blooms and eutrophication, suffocating marine life, and they are also known to do more harm than good by *overfertilizing* plants.

There are several different composting methods that can be used to process frass, and they are generally classified into aerobic and anaerobic composting processes.

Aerobic Composting

As mentioned, the method of aerobic composting requires the presence of oxygen. This degradation process is facilitated by the presence of microorganisms in the organic matter, which generates heat as they break down said organic matter. The heat generated helps accelerate the breakdown of macronutrients and can even kill off pathogens and unwanted weeds! However, the presence of excessively high heat may lead to nutrient loss. The result is a relatively stable organic product that is rich in minerals.

Heap Method

The Heap method is the most common aerobic composting method used for smaller scale agricultural and horticultural purposes. The heap construction has to be set up at a level area with relatively good drainage to prevent flooding. At the same time, it should also be shaded to prevent it from drying out.

In this method of aerobic composting, the organic matter used is to be divided into three categories – namely soil, brown materials (leaves and branches), and green materials (food waste). The organic matter is then layered, with each brown and green heap separated with a thin layer of soil. This heap is then left to decompose. However, it must be mixed once a week for three weeks to ensure even decomposition and a consistent end-product.

Windrow Composting

When it comes to large/industrial-scale composting, windrow composting is performed instead. This method involves depositing the organic matter in long horizontal rows of large piles (known as windrows) above ground that have to be aerated manually from time to time (EPA, 2021). Each windrow is around 1.2 to 2.4m tall, and around 4 to 6m long – sufficiently large to retain sufficient heat for the composting process. On an industrial scale, we would expect many of such windrows to be lined up alongside each other – thus it comes as no surprise that executing such a composting method will require a huge expanse of land. Given that each windrow must be aerated manually to introduce oxygen and ensure even decomposition, it also requires heavy machinery and is a labour-intensive process (Michel et. al., 2022).

In-vessel Composting

In-vessel composting is also a large-scale processing, but instead of leaving it out in windrows, organic material is collected in a drum or silo-like equipment. This enclosure enables better environmental control, as parameters such as temperature, moisture, and airflow can be altered to favourable levels. Given that the vessel itself is a heavy piece of machinery which requires technical expertise to operate, this processing method is expected to be costly.

Vermicomposting

Unlike the various forms of aerobic composting techniques described above, vermicomposting does not involve the help of heat-loving bacteria present in organic material that we call thermophiles. Instead, earthworms and their associated microbes are utilised to aerate and break down the organic material naturally, leaving an abundance of organic material that can be further biodegraded by microbes into valuable vermicompost as a final product (Pathma & Sakthivel, 2012).

Vermicompost is commonly used to enhance plant growth by increasing the porosity and microbial activity in soil. This not only enhances the ability of the soil to retain water, but it also helps suppress a variety of diseases in plants (Zafar, 2021). The availability of different types of nutrients in the resultant vermicompost depends on the organic matter used, as well as the species of earthworms used (Zafar, 2021). Vermicomposting can be executed with the use of well-designed vermicomposting bins that have holes that allow for ventilation and the introduction of moisture. Additionally, proper earthworm cultures will also need to be purchased or prepared beforehand to ensure that the vermicomposting process runs smoothly.

Anaerobic Composting

Anaerobic composting takes place in the absence of oxygen. To ensure a complete anaerobic environment, a sealed, airless container with a single compartment (known as a digester) is required. This is to ensure that the anaerobes, which are microbes which thrive under anaerobic conditions, have an ideal environment to degrade the organic matter in question. There are generally two types of digesters, mainly dry and wet ones.

No water or liquids are added to dry digesters; while this is this case, the organic matter being digested should be sufficiently moist – e.g., vegetable waste, plants, food waste – to make up a total moisture content not exceeding 15%. On the contrary, wet digesters should include organic matter that are generally moister in nature. These include manure, slurries, and effluent discharges, which are mixed with water to obtain a moisture content of 85% and above (Li et. al., 2021).

In the absence of oxygen, the anaerobes then proceed to metabolise and break down organic compounds through a reduction process (Niladri, 2019). As the organic matter is processed at low temperature and hence at a slower rate, this composting process takes approximately six to eight months, which is slightly longer than the aerobic composting processes. The duration of composting should also be sufficiently long – given the general lack of substrate heat, longer composting periods will generate sufficient acid volumes to destroy harmful organisms instead.

It is also important to note that anaerobic composting is used to generate biogas, which includes methane, hydrogen sulphide. While useful as a renewable energy source, it is also harmful to the environment as methane itself is a potent greenhouse gas that traps a significant amount of heat, contributing to global warming.

Another product of anaerobic composting is compost tea, which is a combination of liquid compost and digestate (organic material post-digestion). This odourless substance is collected after the compost is harvested and is generally used as plant fertilizer as well.

Factors affecting Aerobic and Anaerobic Composting

In order to obtain a relatively stable organic end product, parameters like particle size, moisture content, and oxygen flow should be taken into consideration.

Particle Size

The particle size of the organic matter important in determining its rate of decomposition. A smaller particle size translates to a larger surface area to volume ratio, and thus allows more access for the microorganisms to break down the material. Consequently, the rate of decomposition will increase (EPA, 2021). An optimal particle size of less than two inches in diameter can be achieved through means of grinding and shredding.

A particle size of two inches also allows for better heat insulation. As such, the optimum temperature of the compost (between 57°C and 81°C) can be better maintained during aerobic composting. However, any particle size that is smaller than two inches may prevent proper circulation of air within the material, which is not ideal!

While shredding and grinding of organic matter is necessary in some cases, it is not recommended for certain materials, which include vegetative and herbaceous matter. The result of grinding such materials is a soggy mass, which will make it rather difficult to manage throughout the composting process. Typically, regrinding of the substrate is done towards the end of the decomposition process, serving as a final act of aeration for the compost mix before harvest. As such, there is no one-size-fits-all approach to the grinding or shredding of organic materials, as this is highly dependent on the nature of the raw material being used (Washington State University, n.d.).

Moisture Content

As with all living things, the organisms responsible for composting – be it microbes, microorganisms, or worms, all require water to live and function. Water serves as a transport medium for them, giving them access to the nutrients they need (Zafar, 2021). As such, the moisture content of the organic matter used is of utmost importance in both aerobic and anaerobic composting methods.

Generally, the ideal moisture content of anaerobic compost lies between 65% to 85%, while a lower moisture content of between 40 to 60% is recommended for aerobic composting. Should the moisture content be excessive, the compost mix will be less porous, leading to anaerobic conditions due to insufficient ventilation.

Oxygen Flow

This aspect is particularly pertinent to aerobic composting, since anaerobic composting is completely devoid of oxygen – introduction of oxygen would be detrimental in this case as the anaerobes will not be able to survive.

Bulking agents such as wood chips and shredded cardboard/newspaper are generally used to aerate the compost pile, promoting oxygen flow and speeding up the decomposition process.

Studies have shown that frequent aeration throughout the first two weeks of aerobic composting will not only stabilize the compost mix, but also helps to shorten the period of active decomposition (Washington State University, n.d.). This is beneficial as it reduces the overall time and land area required, making the whole process a more streamlined and efficient one. Nevertheless, too much aeration is also a bad thing, as the compost pile will dry out too quickly and impede the composting process – remember that moisture content is still key for decomposition!

Temperature

Temperature is a key when it comes to promoting rapid composting. The organisms involved in aerobic composting releases heat as they break down and metabolise the organic matter. Consequently, the compost mix can reach temperatures of approximately 60°C (Zafar, 2021) – this is favourable as it can eradicate pathogens and pests, as well as inactivate the seeds of pesky weed species. A favourable temperature range of the compost mix should be between 57°C and 71°C. However, prolonged high temperatures within the compost mix may lead to the loss of nitrogen, which is an essential mineral required for plant growth. To mitigate this, other factors such as moisture content and aeration (oxygen flow) should be closely monitored, as these parameters are closely linked.

pH Levels

Compost organisms are only able to thrive in a rather limited pH range, which makes this parameter an important one to look out for. An ideal pH range for compost mixes should lie within 5.5 to 8, and the pH should be monitored closely and adjusted accordingly to keep it within the acceptable range.

Biodegradability of Feedstock Material, Ratio of Carbon & Nitrogen

The organic matter used for composting is undeniably the star of the show; the success or failure of the compost depends heavily on the type of organic matter that is used.

Firstly, organic materials used for composting should be sufficiently biodegradable and suitable. For instance, oily substances such as butter and salad dressing should be avoided, as organisms will have a hard time breaking down such products.

The total carbon and nitrogen content of the material used should also be considered before composting; carbon and nitrogen both provide energy and helps build the cell structure of the organisms that help break down the organic matter. Should the amount of carbon be excessive, nitrogen robbing can occur – this is when microbes make full use of the excess carbon as an energy source, which also draws up nitrogen in the process. The nitrogen gets temporarily locked up within the microbes, making them unavailable for plants; the quality of compost as a fertilizer will decrease as a result (Gotaas, 1956). Carbon is also required by the microbes to convert nitrogen into protein – should there be insufficient carbon to facilitate protein conversion, the nitrogen will also be expelled in the form of ammonia, which also depletes the nitrogen store in the resultant compost (Gotaas, 1956).

An ideal ratio of 20:1 (C:N) can be attained by adding organic matter containing cellulose. Additionally, blending or proportioning can be carried out to achieve the ideal ratio of carbon, nitrogen, and moisture content.

Comparison Between Aerobic and Anaerobic Composting

Resultant compost and liquid fertilisers derived from anaerobic processes are generally of higher quality as compared to those conditioned through aerobic processes, as it retains most of the nutrients required for plant growth (Chavez-Rico et. al., 2022). Anaerobic composting is also less of a hassle to carry out, since the compost mix does not require frequent mixing and aeration, resulting in a less labour-intensive process.

While anaerobic composting provides better quality compost at a lower maintenance cost, it also comes at the price of a longer composting duration as compared to aerobic composting. The total anaerobic composting duration can take up to 6 to 8 months as compared to 3 to 6 in aerobic processes, due to the slower rate of decomposition by anaerobes (Zafar, 2021). Moreover, high levels of ammonia, methane, and other organic gases are produced as by-products – some of which are harmful to the environment as greenhouse gases or just simply unpleasant-smelling. Nevertheless, these biogases are also valuable as renewable sources of energy.

As for aerobic composting, its shorter period of composting is subjective as it is also highly dependent on environmental conditions. Unlike anaerobic composting, which occurs in a consistent, sealed environment, aerobic composting occurs in an open environment. Not only does this affect the temperature, moisture, and oxygen flow consistency within the compost pile, the smells produced also likely attract unwanted pests like flies to lay eggs in the compost pile. However, natural defence mechanisms such as the heat and acid produced may serve to mitigate this problem of pests and pathogens (Natural, 2021). Thorough monitoring of the conditions within the compost pile is also required to ensure optimal conditions, given that the mix is largely exposed to the environment as well.

Fermentation

Apart from composting, fermentation is also used as an alternative method to recycle food waste and break down organic waste. During fermentation, microorganisms such as yeast or lactic acid bacteria are inoculated and are responsible for chemical reactions in the organic matter mix, which enriches it with nutrients and amino acids (Malo & Urquhart, 2016). The main difference between composting and fermentation is that composting facilitates the breakdown and decomposition of matter, while fermentation facilitates physicochemical changes instead (Chavez-Rico et. al., 2022). Usually, in the case of fermentation, organic matter is treated and conditioned without aeration or any other form of extra processing (Hitman et. al., 2013). The Bokashi method is one commonly used fermentation method.

Bokashi Method

'Bokashi', Japanese for 'fermented organic matter', is a fermentation technique developed in Japan in the early 1980s that has its roots in ancient Korean or Japanese farming. It utilises a special mix of lactic acid bacteria, non-sulphur bacteria, as well as yeasts, producing a yellowish Bokashi leachate by-product as an effective liquid fertilizer (Lim et. al., 2021).

A Bokashi bucket, which is a sealed bin, is used in the process to facilitate an anaerobic environment which allows for fermentation to take place. Aside from organic matter, an organic accelerant made up of a mix of bran and carbohydrate sugars (molasses) is also added. This accelerant supplements the mix with nutrients essential for microbes and bacteria responsible for fermentation. Towards the bottom of the bin, there should be a permeable plastic grate to allow for the liquid leachate by-product to pass through, and a tap should also be attached to the bottom of the bin to allow for the leachate to be dispensed and collected.

The Bokashi setup involves placing organic matter layered with the Bokashi mix in the bucket, which is subsequently sealed and left to ferment for approximately 10 to 14 days (Matters, 2021). Throughout this process, the leachate (or liquid compost, generated as a by-product of fermentation) should be drained off daily. The resultant leachate is usually diluted before being used as a plant fertilizer. The final product of the fermentation process is a mass of pickled compost. This compost is highly acidic, owing to the fermentation process, and is unsuitable for immediate use – thus, it is often first buried to neutralise its acidic pH level.

Comparison Between Composting and Fermenting Frass

The fermentation process wins out composting in terms of nutrient retention, granted that carbon, nitrogen, and phosphorus are better preserved in fermented compost (Chavez-Rico et. al., 2022). On top of that, a large amount of compost yield is also lost. Statistics by Hitman et. al., (2013) show that 60.2% of starting organic material was lost through composting, while only 3.2% were lost through fermentation – the quality of frass produced through fermentation is therefore of a higher quality with better yield.

Composting frass requires daily mixing and aerating to ensure optimal decomposition, while additional processing steps are not required for frass fermentation. As such, composting frass could prove to be a more labour-intensive process. Moreover, frass fermentation via the Bokashi method has a lower carbon footprint than composting since biogases are not produced. Fermentation also has a shorter processing period as compared to traditional composting. As such, frass processing via traditional composting methods requires more time and labour.

While frass fermentation through the Bokashi method may seem more ideal than traditional composting methods, the preparation of the Bokashi mix and bran mixture used in fermentation can be tedious, time consuming and even expensive. Given that the amount of mix required is proportional to the volume of frass to be fermented, larger batches of frass will require more work and higher expenditure. Therefore, smaller batches of frass processing should work better for fermenting via the Bokashi method.

Other constraints should also be considered when deciding between the Bokashi fermentation method and the more traditional composting methods. For instance, the organic matter used can be a limiting factor when it comes to fermentation. Generally, only food waste is used in fermentation (Hitman et. al., 2013), but a larger variety of organic waste, which includes garden waste, can be used for composting.

Insect Frass Processing

Typically, organic material like garden and food waste are more widely used for processing. However, frass produced by insects such as our Black Soldier Flies (BSFs) can also be further processed to enhance its performance as a plant fertilizer. Bottles of fermented insect frass extract sold as garden supplements can commonly be found on e-commerce websites. The ingredients of these frass extracts include organic molasses and lactic acid bacteria, which are typically used in the Bokashi fermentation method – as such, the frass extract is likely the same liquid fertilizer leachate that is collected during the fermentation process.

While existing products did not specify the type of insect frass used, the production methods of frass produced by BSF were explored. Studies have shown that BSF frass can be utilised as a soil nutrient source, but the processing methods described can aid in improving its properties even more.

As a study done by Klammsteiner et. al. (2020) shows, the number of coliform bacteria (typically present in the environment) present in insect frass will increase over time as the frass matures. Bacteria from both the soil and frass might end up competing for nitrogen, which is an essential macronutrient not only for their survival, but also for plant growth in a fertilizer! While the existing soil bacteria was eventually shown to outcompete the coliform bacteria (Klammsteiner et. al., 2020), processing methods such as composting can be used to control the bacterial population altogether, especially when mature frass is being used.

While insect frass can be used as-is as a soil fertilizer or supplement, its moisture content is a key factor that can affect soil quality. Over time, insect frass may absorb moisture from the environment, which increases its moisture content. When inoculated into the soil as a supplement or fertilizer, clumping of material may occur, resulting in reduced soil aeration and miscibility. This could potentially result in inadequate oxygen supply to the soil, which can prove detrimental to plants. Frass processing methods like composting or anaerobic digestion can help alleviate this problem (Klammsteiner et. al., 2020).

Processing methods such as composting puts the insect frass through harsh conditions that are hot and acidic, which aids in damaging hardy organisms that we do not wish to be in the resultant frass product – these include seeds, pathogens, and moulds.

Aside from heat treatment, frass can be pulverised through an alternative processing method of grinding. This facilitates seed removal through crushing and reduces the particle size of the resultant frass. This translates to an increase in surface area, which allows for better nutrient absorption by plants. Finer insect frass particles also help to enhance its insecticidal properties – for instance, fine frass particles have been found to be toxic to wireworms (Vickerson et. al., 2014), which are known to be agricultural pests.

Conclusion

In summary, insect frass used as plant fertilizers have been shown to adequately supplement the soil with nutrients required for plant growth. However, it is recommended for them to undergo further processing to improve its nitrogen content, gas permeability, and insecticidal properties – this yields an enhanced fertilizer product that benefits soil health and quality.

Common processing methods like composting and fermentation treatments were suggested and tested. Though better-quality frass was produced through fermentation, it is ultimately more applicable to small-scale frass processing and a limited variety of organic materials. Good quality frass from fermentation also comes at the expense of higher processing costs. To conclude, composting and fermentation are two ideal methods for frass processing, depending on the nature of raw organic materials used, as well as the economical requirements of the finished end-product.

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