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White Paper

Assessing the effect of brewing time and added microbial foods on the quality of aerated compost tea.

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Abstract

Compost tea (CT) is a water based microbiological inoculant containing high levels of bacteria and fungi produced from compost. This is applied to crops improve soil and plant health and increase plant growth. This investigation aimed to identify the optimum conditions to produce a CT containing the highest levels of active microbial biomass. By varying the components of the CT mix and length of time that it was brewed, an ideal mix of compost, molasses and humic acid with a brew time of 24 hours was identified as providing the highest overall active and total microbial biomass.

Key words: Aerated compost tea; Bacteria; Compost; Fungi; Humic acid; Molasses; Soil microbiology

1. Introduction

Compost tea (CT) is a water based microbial inoculant (MI) ideally containing high populations of beneficial bacteria and fungi. It is produced by a method of 'brewing' in which compost is steeped in water for a defined period. The resulting 'tea' is popular with growers due to its benefits on soil fertility and disease suppression. It is thought that once the 'brewing' process is finished and the resulting compost tea is applied to the plants and soil it will add microorganisms to soil.

Whilst soil and compost based plant sprays have been used since the 1920's, more modern research began in this area in the 1980's. Results from scientific trials are still scarce with the limited results and experiences suggesting that plant diseases have been suppressed in some cases by treating with CT whilst in other instances no effect was observed on disease suppression or CT appeared to increase disease severity.

Compost tea can be produce using different methods, either aerated or non-aerated and with or without additives based on the needs of the soil. In the non-aerated method there is no attempt to supply the organisms with supplementary oxygen (Scheuerell, 2003), resulting in anaerobic conditions during the brewing process, which limits growth of microorganisms (Kelley, 2004). In the aerated method the mixture is deliberately aerated (Ingham, 2005; Kelley, 2004; Scheuerell, 2003), allowing large numbers of beneficial organisms to populate the mixture (Ingham, 2005).

Irrespective of aeration, all methods intentionally ferment the compost to culture and extract the beneficial microorganisms and nutrients in the original compost. Both methods require a fermentation vessel, compost, water, and an incubation (brewing) period. Aerated production also requires mechanics and energy for continuous air addition often through an air stone. Studies have suggested that oxygenation (aeration) during the brewing process encourages the growth of beneficial microorganisms (Ingham, 2005) whilst a lack of oxygen may increase the growth of human and plant pathogens (Ingham, 2005; Brinton 2004; Scheuerell, 2004).

Additives such as molasses and humic acid can be added during the brewing process to promote selective growth of microorganisms. Humic acid is often selected as a fungal food source whilst the complex sugars in liquid

molasses provide a source of food for bacteria (Ingham, 2005). These nutrients should be added with care as they have the ability to both increase or inhibit growth rates of the different microorganisms (Scheuerell, 2004).

Whilst there is little data in scientific literature that directly compares CT production processes (Scheuerell, 2006) the available data suggests that CT produced can be inconsistent from batch to batch. The inconsistency has been associated with several factors that affect the production process including the type of compost, the compost to water ratio, brewing time, additional nutrients and supplements and aeration.

The general understanding is that a good compost with high microbial diversity has the potential to make a good CT! A poor compost will always make a poor CT! The production of CT cannot improve on the original quality of the compost; therefore, the quality of the starting compost is critical to maximise the biomass of beneficial microorganisms in the CT (Ingham, 2005). Ideally it should contain all the important groups of organisms that are typically found in correctly functioning soil including bacteria, fungi, protozoa and nematodes.

The optimum ratio depends on the brewing method and equipment used. Too little compost will result in dilute tea with few nutrients or organisms. Too much compost means not everything available is extracted. It may also be possible to overload the brewer meaning that efficient water flow and aeration aren't possible (Ingham, 2005)

The typical brew time for an aerated CT is 24 hours, as specified in 'The compost tea brewing manual' (Ingham, 2005), however the optimum brewing time is the time that gives a balance between the extraction of nutrients and the growth of the organisms, ideally when most of the nutrient and microorganisms have been extracted into the liquid. Temperature, humidity, evaporation and other abiotic factors will influence this.

Introducing microbial foods to the CT mix can increase microbial populations but these should be used with care (Ingham, 2005; Scheuerell, 2003). In an aerobic environment, excess bacterial and fungal growth resulting from the addition of nutrients can cause higher oxygen consumption that is detrimental to maintaining aerobic conditions, and the liquid may become anaerobic (Ingham, 2005). The addition of molasses has been found to assist in the growth of human pathogenic bacteria (Duffy *et al*., 2004; Scheuerell, 2003) however this will not happen if the pathogens are not present in the compost to begin with (Ingham, 2005).

It is thought that aerobic conditions maintain and promote the presence and growth of the beneficial soil microorganisms. Whilst most of these organisms require fully aerobic conditions to thrive, plant and human pathogens generally require reduced oxygen. Therefore if oxygen becomes limited, human and plant pathogen populations are likely to increase (Ingham, 2005; Scheuerell, 2003).

2. Materials and methods

The brewers were made by fitting 20 L plastic drums with an air stone attached to a pump with a 6 mm airline with an in-line check valve.

Each drum was filled with 14 L water and aerated over night to dechlorinate. The pump raised above the brewer for added safety.

The high quality, fungal dominant compost for compost tea was added to the bucket followed by the addition of the microbial foods molasses and/or humic acid (See Table 1) and the solution mixed. The aeration provided a continuous flow of air, creating enough movement to keep the compost tea mixing throughout the brewing process.

2.1. Experimental design

The experiment took place in two parts each, with three treatments and three replicates per treatment (Table 1), over two five day periods (30.1.2017-3.2.2017 and 13.2.2017-17.2.2017). Readings for active bacteria, total bacteria, active fungi and total fungi were taken at 12, 24, 48 and 72 hours. The presence of protozoa and nematodes were noted.

Prior to the start of the experiment the compost and water used in the brewer underwent a full biology, to determine the base levels of the microorganisms in the brewer, and chemistry test.

Table 1 Volume of compost, water, humic acid and molasses (*Compost 5% volume of water) based on recommendations (Ingham, 2005).

Group	Mixture	Compost*	Water	Humic acid	Molasses
A	1	700 mL	14 L		
	2	700 mL	14 L	36 mL	
	3	700 mL	14 L		36 mL
B	4	700 mL	14 L	36 mL	36 mL
	5	700 mL	14 L	72 mL	72 mL
	6	1400 mL	14 L	36 mL	36 mL

The air temperature was recorded throughout the duration of the experiment using two Tinytag temperature loggers (Gemini Data Loggers (UK) Ltd., Chichester, UK) placed at intervals between the brewers. The temperature data was collated using Tinytag explorer software (Gemini Data Loggers (UK) Ltd., Chichester, UK). CT water temperatures ranged between 15°C and 19°C during the investigation whilst the brewers were maintained at ambient temperature between 12°C and 22°C.

3. Results

3.1. Bacteria

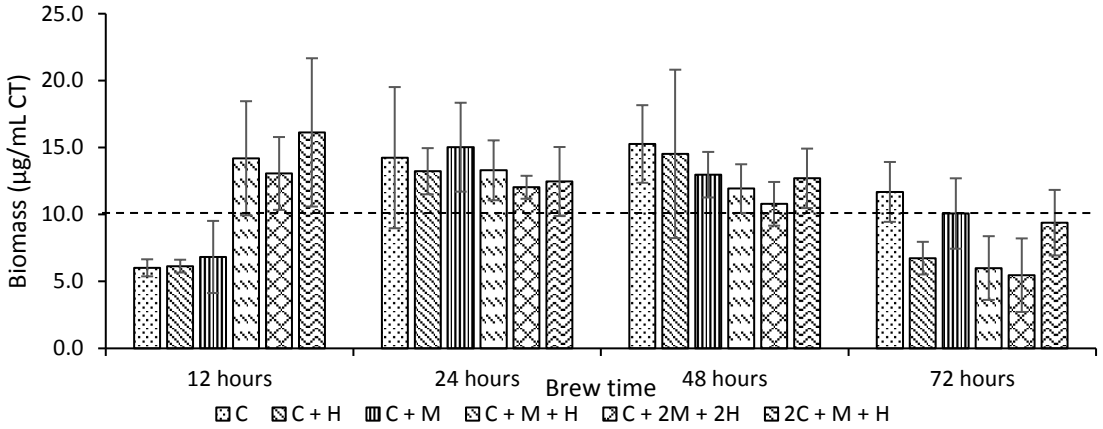

Figure 1 Active bacteria (Guideline biomass indicated by dotted line. Values should not be below this.)

Active Bacteria biomass was similar across all the treatments (Figure 1) with levels equal to the guideline at 24 and 48 hours for all treatments. The active bacteria biomass in the CT decreased in all treatments with 72 hours brew time.

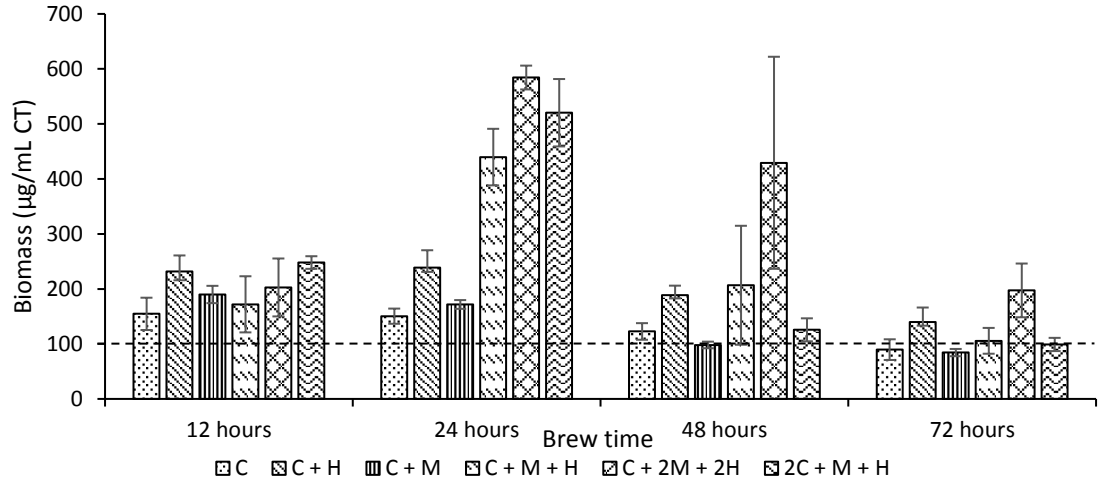

Figure 2 Total bacteria (Guideline biomass indicated by dotted line. Values should not be below this.)

The total bacteria biomass (Figure 2) was generally greater when more bacterial foods were added compared to the volume of compost (treatment C + 2M + 2H). This was most apparent at 24 and 48 hours brew time when the total bacteria biomass was significantly higher than the guideline values.

3.2. Fungi

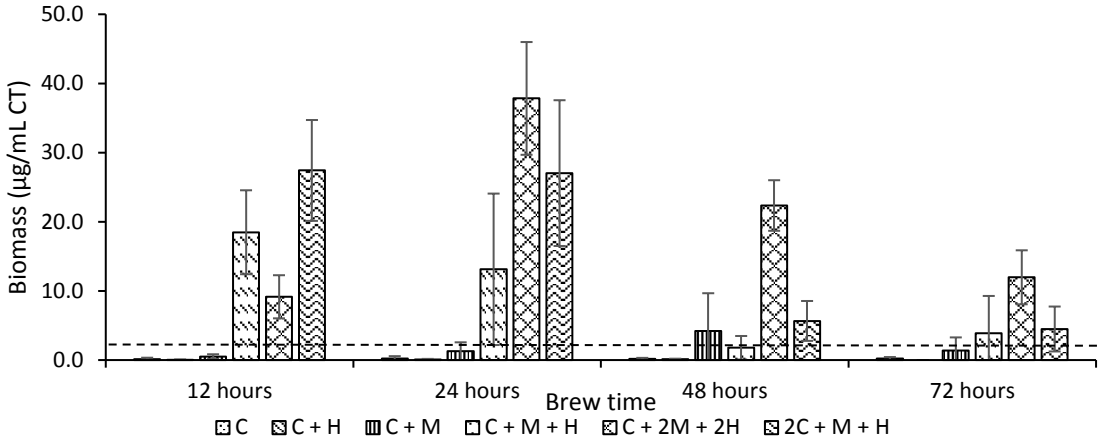

Figure 3 Active fungi (Guideline biomass indicated by dotted line. Values should not be below this.)

Active fungal biomass (Figure 3) was generally greatest in the CT treated with double the volume of molasses and humic acid. Whilst increasing the volume of compost initially produce a larger active fungi biomass (12 hours) the biomass didn't increase significantly with a longer brewing time.

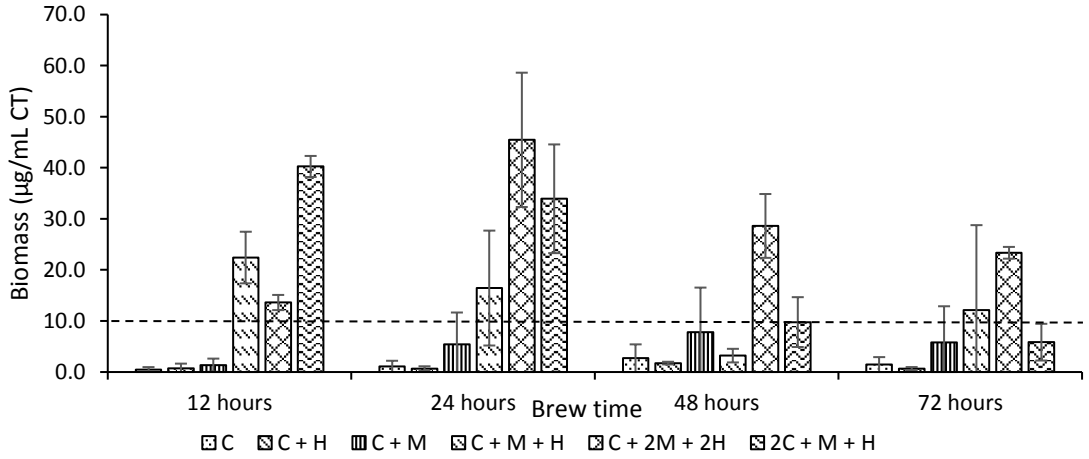

Figure 4 Total fungi (Guideline biomass indicated by dotted line. Values should not be below this.)

Total fungal biomass appeared to follow the same trend as the active fungi biomass with the highest levels initially observed in the CT with double the amount of compost. However, an increase in total biomass was only seen in the CT with double the molasses and humic acid. These levels remained above the guideline over the full 72 hour brew period.

3.3. Biomass ratios

The bacteria showed increased activity levels (Table 2) during the first 48 hours of brewing and then maintained these levels over the remaining 24 hours. Despite the increase in activity levels, the active bacteria / total bacteria levels were lower than the guideline value for all treatments.

The fungi were active throughout the whole of the investigation for treatments 4, 5 and 6. The active fungi/ total fungi levels for these three treatments were above the minimum guideline value for the duration of the investigation.

Table 2 Active/ total biomass ratios of bacteria and fungi across the different treatments

Treatment	*Active bacteria / Total bacteria (Guideline: 0.2 – 0.5)*				*Active fungi / Total fungi (Guideline: 0.2 – 0.5)*			
	12 Hours	*24 Hours*	*48 Hours*	*72 Hours*	*12 Hours*	*24 Hours*	*48 Hours*	*72 Hours*
C	0.04	0.09	0.12	0.14		0.18	0.05	0.12
C + H	0.03	0.06	0.07	0.05		0.05	0.08	0.00
C + M	0.04	0.09	0.13	0.12	0.48	0.31	0.33	0.09
C + H + M	0.09	0.03	0.07	0.06	0.80	0.72	0.49	
C + 2H + 2M	0.07	0.02	0.03	0.03	0.66	0.85	0.79	0.51
2C + H + M	0.06	0.02	0.10	0.10	0.69	0.78	0.58	0.55

The compost tea was fungal dominant in terms of the active biomass and bacterial dominant in terms of the total biomass (Table 3).

Table 3 Active and total fungi/ bacteria ratios across the different treatment groups

Treatment	*Active fungi / Active bacteria (Guideline: 0.2 - 1)*				*Total fungi / Total bacteria (Guideline: 0.1 - 1)*			
	12 Hours	*24 Hours*	*48 Hours*	*72 Hours*	*12 Hours*	*24 Hours*	*48 Hours*	*72 Hours*
C	0.03	0.01	0.01	0.02	0.00	0.01	0.02	0.02
C + H	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01
C + M	0.07	0.08	0.32	0.13	0.01	0.03	0.08	0.07
C + H + M	0.99	0.93	0.31	0.68	0.14	0.04	0.02	0.09
C + 2H + 2M	0.68	3.17	2.15	2.54	0.08	0.08	0.09	0.13
2C + H + M	1.77	2.43	0.45	0.44	0.16	0.07	0.07	0.06

4. Discussion

Overall the compost tea with the highest microbial biomass and activity was produced with 72 mL of molasses and humic acid compared to the other treatments tested. The CT with the highest overall active and total microbiological biomass was consistently produced at 24 hours brew time.

4.1. Starting compost material

The quality of the compost is key to producing a good CT. During this experiment, the compost used was taken from the same stock for all treatments however the moisture content and microbiology of the compost varied between the two experimental weeks. The moisture content of the compost used in the first half of the experiment was 36%. Whilst still within the guidelines this produced a much less balanced and active tea than the compost with a higher moisture content of 48%. The moisture content of the starting compost is therefore critical to produce the best CT possible with higher microbial biomass and increased active and total fungi values.

The balance of bacteria and fungi in the starting compost also affected the biomass of these organisms in the resulting CT. Whilst the incubation period increased the overall biomass of organisms in the CT, the ratio of bacteria to fungi was generally determined by the starting material. In the first week of the investigation the compost was bacterial dominant and produce a bacterial dominant tea (Table 3) with very low levels of both active and total fungi (Figure 3 + 4). During the second week of the investigation the compost used to produce the CT was fungal dominant with regards to the active biomass. This produced a CT with much higher levels of both active and total fungi, well above the guidelines (Figure 3 + 4). Therefore, to produce a fungal dominant tea, a fungal dominant compost is ideal.

4.2. Treatment

The various combinations of compost, humic acid and molasses all increased the active and total biomass in the CT compared to the levels in the starting compost. The highest active and total biomass results however were produced by the CT mix containing 700 mL compost combined with 72 mL of molasses and 72 mL of humic acid. This combination particularly increased the fungi biomass with a significant increase in both the active and total fungi levels in the resulting CT. Whilst the most active CT produced was fungal dominant, to understand the full benefit and impact of this inoculant further tests on the soil and plants would be necessary to account for fungal spores that have the capacity to germinate under the right conditions.

Increasing the quantity of the two food sources provided the best results with a brew time of 24 hours, more so than increasing the volume of compost added. The CT with double the food source increased the active biomass by a factor of 12, compared to the starting compost, and the total biomass by a factor of 5. In comparison, the CT produced with compost and water without any additional sources of food only increased the active biomass by a factor of 7 and the total biomass by 0.86 compared to the starting compost.

4.3. Brewing time

Under the conditions tested, in general, 24 hours was the optimum brew time to produce the most active CT with a high bacterial and fungal biomass. A brew time of greater than 24 hours did not increase the biomass availability in the CT and 12 hours was not long enough to reach the maximum organism biomass. Whilst this confirms the brew time of 24 hours recommended by Elaine Ingham (2005), further microbiological analysis of samples taken at intervals between the 12 and 48 hours would provide a more details as to the optimal brew time to give the best CT.

4.4. Further work

We have confirmed, under the described experimental condition, that 24 hours is the optimal brew time, within the times tested, for CT and that addition of molasses and humic acid is more beneficial in terms of increasing microbiological biomass than additional compost. Further work is however necessary to determine the impact of the starting compost on the resulting CT. This could be achieved by using compost samples with different microbiological profiles and comparing the CT produced. Further investigations using each of the food sources, molasses and humic acid, added to the CT mix individually would provide more detail as to the effect of these food sources on the microbiology of the CT.

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