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# Comparison of Dewar Self Heating Test, Solvita Compost Maturity Test and the OxiTop® measuring system to establish stability and maturity of composted material for use in growing media.


## A project report of

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# ABSTRACT

Compost stability and maturity are important parameters for the further use of compost in growing media, because the use of poorly stabilized and matured compost may cause numerous problems, such as poor plant. Reliable methods are therefore needed. To determine compost stability many different methods are in use, including chemical, physical analyses, microbiological and plant assays. The aim of this study was to establish correlations between self heating, determination of respiration velocity with the OxiTop® system and the Solvita® compost respiration test, evaluate variations within each method, with the ultimate aim of selecting a procedure for evaluation of stability in Bord Na Mona producing compost.

For the study 48 samples were collected from fresh, semi-matured and matured piles from the Bord Na Mona Kilberry Composting Facility Co. Kildare in Ireland. Self heating, OxiTop and Solvita tests were done, as well as chemical and physical analyses.

The results of chemical and physical analyses showed considerable variation in samples of the same age and no significant trends appeared during the maturation process. The comparison of self heating, OxiTop and Solvita always showed a good correlation between each method of at least $R^2 = 0.84$. The highest correlation was found between self heating and OxiTop measurement ($R^2 = 0.92$). In the comparison, the Solvita Test always showed the lowest correlation values and also exhibited much higher variation than the other two tests, especially for matured samples.

But as the Solvita Test is easy to handle, it could be used if only a quick overview is needed, as for example on-site. However, it costs around € 35 per sample. The self heating is also very easy to handle, but needs 5 to 10 days to obtain results. Also, as soon the samples don't show any self heating, it's not possible to distinguish between stable and very stable samples.

The OxiTop results give much more details about the sample, as moisture and ash has to be done as well to determine the amount of sample. But the OxiTop system needs a lot of time and only few samples can be done, as the number of samples that can be tested is limited by the number of OxiTop bottles. The result

for the respiration velocity could theoretically start at 0 mmol $O_2$/kg OS/h. The samples gave OURs of 5 to 116 mmol $O_2$/kg OS/h. But most of the samples only showed an OUR between 5 and 15 mmol $O_2$/kg OS/, which is considered stable. The OxiTop showed several problems and unsolved questions. Sometimes the pressure increased suddenly, after a normal decrease without obvious reason. This could be due to a leaky bottle and the OUR couldn't be calculated. Because the amount of measurement heads was a limiting factor and due to a lack of time, it was not possible to do samples in duplicate or repeat samples. With fresh samples the pressure drop wasn't linear, but exponential. Even reducing the amount of organic matter of samples from fresh piles didn't result in a linear decrease in pressure drop. Also major concerns arise when repeating samples, especially again for fresh piles, where stability may change within a few days.

For Bord Na Mona there are still a few questions that have to be answered. It's not clear which stability stage is needed for the use of compost as growing media and which self heating and growing media result represent this stage. In the light of costs associated with the Solvita Test, and the inherent variations seen with the OxiTop test, the self heating as a cheap, easy to handle and reliable method may be the best method to determine the stability for Bord Na Mona, out of the three compared methods.

# 1. INTRODUCTION

For the further use of compost, stability and maturity are important parameters. Composting can be divided in three stages.

- In the first relatively short stage, a rapid decomposing of simple available, high energy organic substances such as carbohydrates and proteins takes place. As a result of this primarily bacterial process, the compost piles heat up and correspondingly microbial activity increases.
- In the next stage of 2 to 12 months maturing takes place, where cellulose and hemicellulose is decomposed primarily by actinomycetes and fungi. The decomposition rate and the heat release are reduced, due to those compounds being harder to decompose and thus yield less energy.
- Stable compost is the result, and only very slowly decomposing of the remaining lignin and lignocellulose takes place (Henry and Harrison, 1996).

Most researchers define stability as the microbial degradation rate of the organic matter under aerobic conditions (Haug, 1993) or as the resistance of compost organic matter to further degradation (Sullivan and Miller, 2001, Buchmann et al., 2001). A higher stability corresponds to a lower degradation rate. Maturity is the degree of completeness of composting (Buchmann et al., 2001) and this is important for a particular end use, in the case of growing media this means “well stabilised compost”.

Poorly stabilized and immature compost may cause a number of problems during storage, and result in poor plant growth if used in growing media. Development of phytotoxic compounds, reduced oxygen and/or available nitrogen (Buchmann et al., 2001), mycelium growth and odours discouraging consumers (Henry and Harrison, 1996) or a potential source of surface and groundwater contamination (Bio-Logic, 2001) are a few examples of negative effects. This makes it important to have reliable compost stability tests. There are a wide range of methods and approaches in use (see Table 1).

Table 1: A few methods to predict compost maturity (Inbar et al., 1990)

| General Method | Criteria |
|---|---|
| Chemical analyses | Carbon/nitrogen ratio, water soluble ions, water soluble organic matter, cation exchange capacity, crude fiber analysis |
| Physical analyses | Temperature, colour, particle size, water and air content |
| Microbiological assays | Indicator microorganisms, respiration rate, microbial activity and biomass, suppression of plant pathogens |
| Plant bioassays | Cress germination test in water extract, rye-grass growth in compost containing mixtures, seedling development in compost and water extracts |
| Spectroscopy | Solid state CPMAS $^{13}C$-NMR, Infrared – FTIR, DRIFT |
| Degree of humification | Total humic substances, functional groups content, content and ratios of humic and fulvic acids and non-humic fractions |

Compost stability can be expressed through chemical, physical and biological parameters. During the maturation process the compost undergoes certain changes. So, chemical parameters as C/N ratio, $NO_3/NH_3$ ratio, pH and electrical conductivity are other opportunities to determine stability and maturity. For example in several literature reviews (for example Wu et al., 2000) electrical conductivity and pH are discussed as possible stability indicators. In general pH increase up to > 8 during early stages of composting and then decrease slowly but steadily. As an advantage those methods are cheap and quick, which makes them popular in the laboratory. But these parameters are not directly related to stability. Moreover, the chemical values are not absolute and are highly dependant on the composition of the starting material.

The degradation rate (reflecting stability) of organic matter by microbial activity can directly be determined from its oxygen uptake rate or respiration rate (OUR), $CO_2$ production or heat production rate (Veeken, 2003). Buchmann et al. (2001) recommend for their CCQC compost maturity index to determine stability and maturity:

- Determination of C:N ratio
- At least one test for $CO_2$ evolution, respiration, oxygen demand or self heating (group A)
- And at least one test for ammonium:nitrate ratio, $NH_3$ concentration, volatile organic acids concentration or plant growing tests (group B).

In this project three methods of group A were chosen to compare their results for compost stability and for their handling in the everyday laboratory use: Dewar self heating, determination of biological oxygen demand with OxiTop® system and the Solvita test.

The main principle of the self heating test is based on sample heating due to cell metabolism leading to production of energy as heat by the microorganisms in the samples. This test shows therefore the biological activity of the sample. The more mature the compost sample is, the lower is the self heating. Due to the temperature rise, the compost is classified in 5 official stability classes (Kehres, 2006). But the measured temperature is not directly related to dH (heat production) as temperature is a result of heat production and heat removal (Veeken, 2003). This method was adopted as an official standard for compost stability by the German Department of Environment in 1984 (LAGA , 1984).

The OxiTop® system to determine the biological oxygen demand is in discussion as an official standard for compost stability in the European Union (Prasad, personal communication). The use of the OxiTop system allows an online respirometric measurement by determination of pressure variation at a constant temperature of 30 °C. If the sample in the closed vessel on constant temperature uses oxygen, the pressure will increase. In the case of gas production pressure will rise. The OxiTop-C Measuring Head will measure and record the pressure on the duration of the measurement of 120 hours (Operating Manual OxiTop®). A typical pressure drop is shown in Figure 1. In the beginning the pressure increases due to the rising temperature. After a possible lag phase the pressure decreases linear caused by microbial oxygen

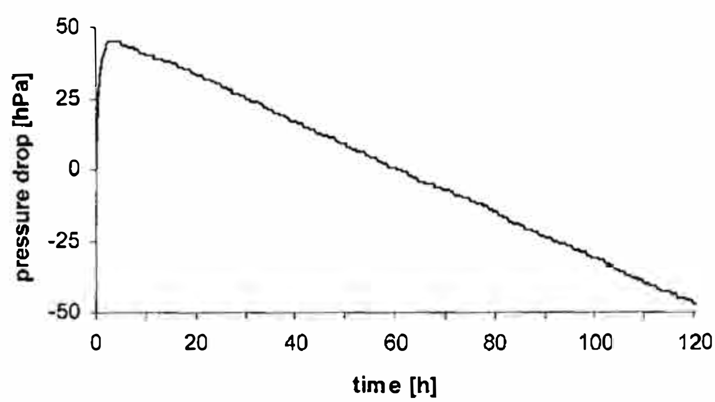



**Figure 1:** Typical pressure drop for an aerobic degradation test with OxiTop. First the pressure increases due to the increasing temperature. Afterwards the pressure decreases linearly due to $O_2$ consumption in the bottle.

consumption. The respiration velocity (OUR) is determined by linear regression of the oxygen consumption (COU) in this period (Veeken, 2003).

The COU (mmol $O_2$kg OS) is calculated based on the pressure drop (dP) of the head space accordance with

$$COU = dP/ (83.14 * (273.13 + T)) * V_{gas} / (W * DS * OS)$$

Where dP = pressure drop of the head space (mbar or hPa)
T = temperature at which measurement is made
W = start weight of the sample [kg]
DS = dry weight content of the sample [kg]
OS = organic material [kg]
$V_{gas}$ = volume of the gas phase

The OUR (mmol $O_2$/kgOS/h) is calculated using the COU value and the relevant time duration.
OUR = COU /dt

Where dt = time interval in hours within dP is measured

The Solvita maturity test provides a simple, inexpensive relative test of compost stability and $NH_3$ emission for a wide variety of composted manures (Changa, 2003). The test is based on two paddles for, respectively $CO_2$ and $NH_3$ to determine their evolution rate in a 4 hours time period in closed jars.

Each test method has advantages and disadvantages, so an aim of this project is to establish correlations between self heating, determination of respiration velocity with OxiTop and Solvita methods, evaluate variations within each method, with the ultimate aim of selecting a procedure for evaluation of stability in Bord Na Mona producing compost.

# 2. MATERIALS AND METHODS

## 2.1. Sampling

Compost samples were collected from piles of different ages from Kilberry Composting Facility Co. Kildare in Ireland. Piles composted for over 20 weeks, semi-matured and fresh piles were selected and 3 to 7 samples were collected from each. The samples with a volume from approximate 4 to 5 l were placed in polyethylene bags and shipped to the laboratory on the same day. Due to exceptionally wet weather conditions, gently drying of the samples was required to reach a moisture content between 55 and 60%. The samples were spread on the work bench and drying was assisted with a ventilator. A drying duration of between 2 and 5 h was required. Afterwards the samples were sieved using a 10.0 mm sieve. The compost samples were used immediately. However, for a few samples of older piles, storage was unavoidable. These samples were kept at room temperature and were dried shortly before using.

## 2.2. Chemical and Physical Analyses

Fresh samples (not dried) were used to determine compost moisture content, pH, electrical conductivity and nutrient content. Moisture content was determined as weight loss by drying the sample at 105 °C for 24 hours (Kehres, 1998). Electrical conductivity and pH were determined by a water extraction (100 ml compost sample : 150 ml water) and pH/ Conductivity meter (pH meter 3310, JENWAY/ conductivity meter 4310, JEMWAY) (Sonneveld, 1990). For the nutrient contents 100 ml of compost sample was extracted in 150 ml DTPA solution (1.47 g calciumchloride-dihydrate and 0.7898 g diethylenetrimaninepentaacetic acid per litre). To determine ash content, the dried samples from moisture determination were ground (< 0.25 mm) and put into the oven overnight (≥ 8 h) at 850 °C. To determine C:N, $NH_3$-N : $NO_3$-N ratio an NPK acid digestion was used. Approx 0.2 g of the dried and ground samples were filled into test tubes and the exact weight recorded. For the digestion 4 ml of 0.05% Selenium/$H_2SO_4$ (5 g Selenium in 1000 ml of conc. $H_2SO_4$) were added and the tubes placed over night on a block digestor (380 °C). After cooling down 50 ml water was added, well shaked, filtered and finally analysed on the auto analyser.

## 2.3. Measurement of stability

### *2.3.1. Self Heating*

The self heating test was done as soon as possible after sampling. Optimised moisture content for this test was determined by "Fausttest" (Kehres, 2006). In some cases the samples were too wet, and thus gentle drying was necessary. To determine self heating ability 2000 ml "Dewar vessels" (Fig. 2) were filled with the samples, tapping the vessel carefully. The thermometer is located in the lower third of the vessel and records maximum temperature. The samples were screened ≤ 10 mm to reach a uniform mixture (Gallenkamper et al., 1993). The vessels were kept open at room temperature for 5 to 10 days. The test is complete after the sample reaches a maximum temperature, followed by a clear decrease in temperature. At the latest the test is finished after 10 days (Kehres, 2006).

**Figure 2:** The self heating takes place in 2 l Dewar vessels with the temperature measurement in the lower third of the vessel.

### *2.3.2. OxiTop®*

The OxiTop test is done with 3 g of organic matter. As a fresh compost sample needs to be used, it's necessary to calculate the sample weight out of organic matter and moisture content. The calculated sample weight was filled into 1 l bottles. 2.5 ml ATU (4 g/l ATU (N-Allylthiourea, $C_4H_8N_2S$)), 10 ml pH-buffer (43.08 g/l $KH_2PO_4$, 88.86 g/l $Na_2HPO_4.2H_2O$), 10 ml macro-nutrient solution (4.3 g/l $NH_4Cl$, 5.4 g/l $CaCl_2.2H_2O$, 4.3 g/l $MgSO_4.7H_2O$, 0.06 g/l $FeCl_3.6H_2O$) and 180 ml distilled water were added and the bottles were left

**Figures 3 and 4:** The OxiTop® Kit contains the controller and the measurement heads for online measurement of pressure changes.

open for 4 hours. The bottles were then closed tight with the OxiTop-C Measuring Heads and started using the OxiTop® Controller C110 (Fig 3 and 4). The samples were shaken at constant temperature of 30 °C for 5 days (Verhagen, 2005). The data is continually saved on a measuring head (Operating Manual OxiTop®).

### *2.3.3. Solvita® Compost Respiration Test*

The Solvita jars were filled to the indicated line. To get the appropriate density the jar was tapped while filling. The samples were left open to equilibrate in the jar for one hour. To commence the test, the two paddles for "Compost $CO_2$" and "Ammonia" were pushed into the samples and the lids of the jars were closed tight. The jars were kept at room temperature. After 4 hours the gel colour of the paddles is compared to the colour chart. Following this, the paddles are placed in the Solvita-Detector (preproduction model) and a reading obtained (Figure 5). Using the $CO_2$ and $NH_3$ test results the Solvita "Compost Maturity Index" is determined by finding the intersection of the two values in the Solvita Table: Compost Maturity Index Calculator. In the case of no or very low free ammonia the index is the same result as the $CO_2$ paddle.

**Figure 5:** The Solvita Test Kit includes per sample one jar , one paddle for $CO_2$, one paddle for $NH_3$ and for the detection two colour charts and a detector.

# 3. RESULTS AND DISCUSSION

For this project 48 samples are assayed for chemical and physical properties, self heating and the Solvita test. For 42 of those samples, results of the OxiTop test are available.

## 3.1. Chemical Analysis

The results of electrical conductivity don't show any correlation to a change during time (figure not shown, data in appendix). An insignificant decrease of the pH was recorded for the samples from the very old piles (data in appendix). There is no significant variation in C:N ratio between younger and older piles. The C:N ratio was always less than 25, which is the maximal ratio to rate compost stability as acceptable (Buchmann et al., 2001). There is no significant trend for $NH_3N:NO_3N$ ratio during the time. However, the $NH_3N:NO_3N$ ratio variation for the older piles is lower, as well as the ratio values themselves. In general the variation of pH, EC and $NH_3N:NO_3N$ ratio is much higher for younger samples. This might be a reason of insufficient mixing of the starting material of the piles, different conditions during decomposing, different feedstocks for different piles or different ages of the feedstocks. Due to the high variation those chemical parameters cannot therefore be used as reliable stability parameters, but they could give some useful indications about the compost process in certain cases.

## 3.2. Comparison of stability methods

To compare the different methods temperature vs. respiration velocity (OUR) (Fig. 6); Solvita index vs. self heating temperature (Fig. 7); and Solvita index vs. OUR (Fig. 8) with a logarithmic regression are shown below. Figure 6 shows with $R^2 = 0.92$, the highest correlation. The other correlations are with $R^2 = 0.84$ also quite good. All the three stability tests vs. the age of the piles showed a very low correlation (Fig. 9, 10 and 11). There is always a data cluster with low activity, indicating that most of the samples were already in the curing stage.

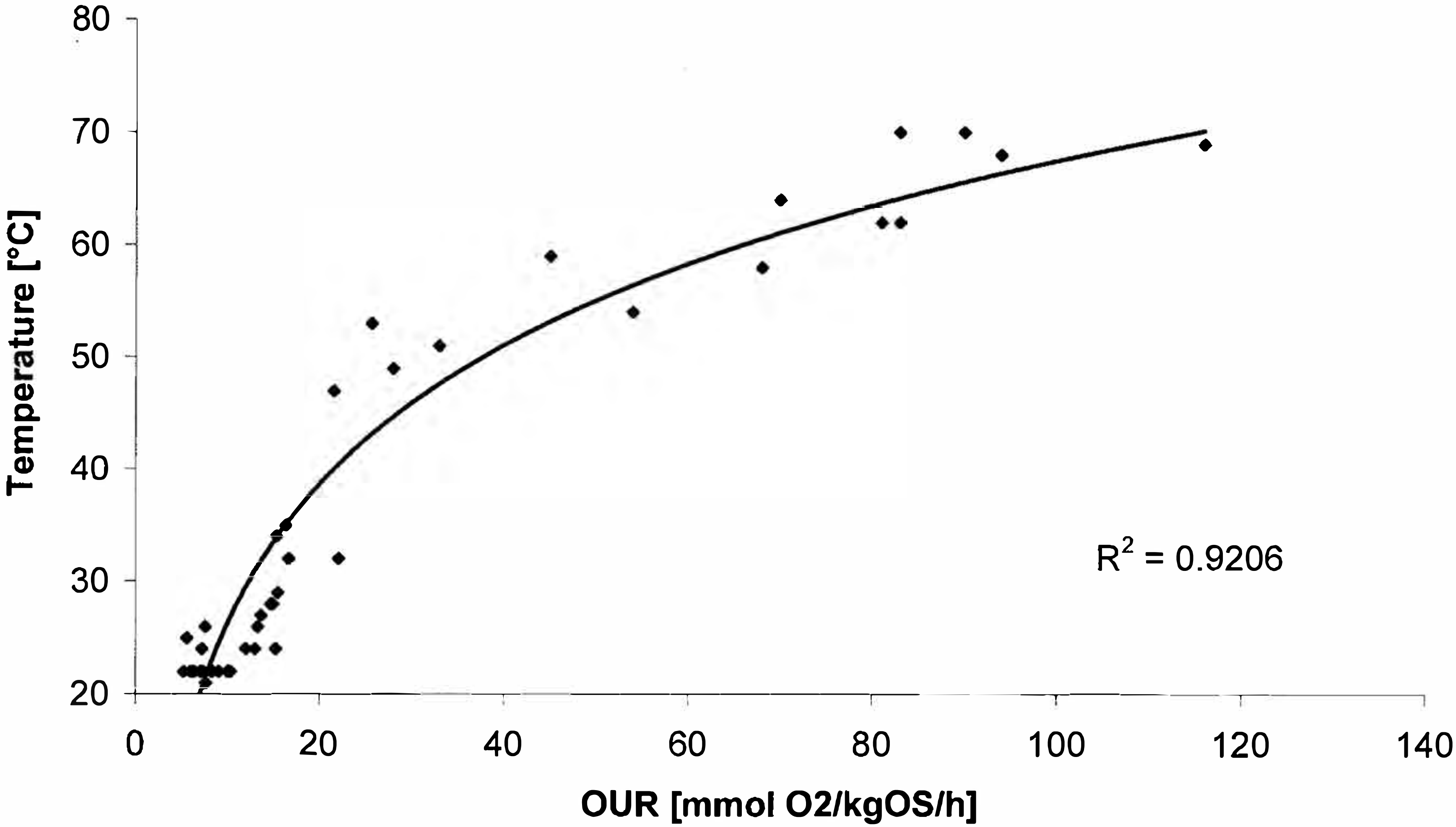



**Figure 6:** The logarithmic regression of the temperature from self heating vs. OUR of the OxiTop system shows an $R^2 = 0.92$. A lot of samples didn't show any or very low self heating as well as respiration velocity between 5 and 15 mmol $O_2$/kg OS/h. The other data values are well scatted around the regression line.

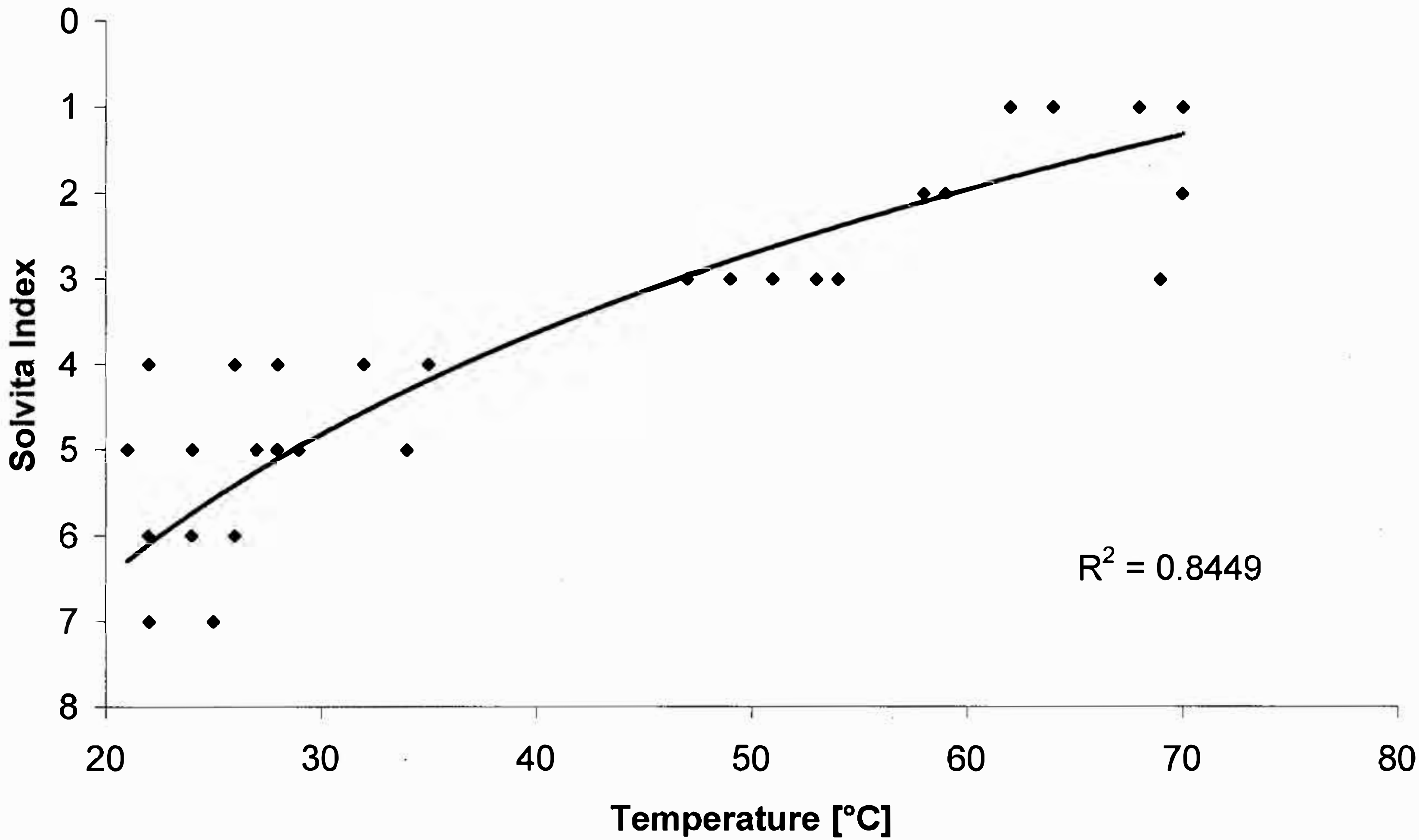
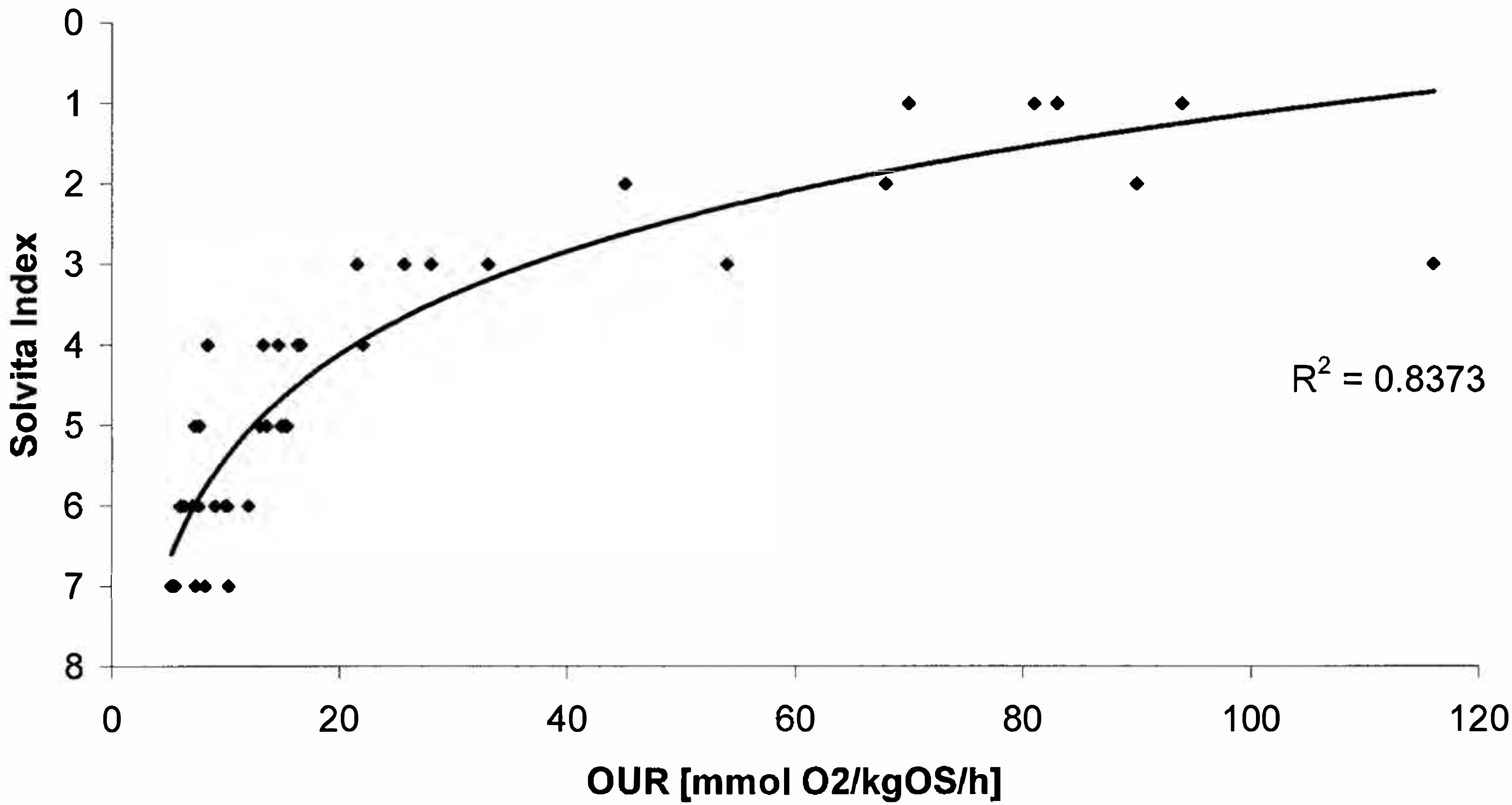



**Figure 7:** The logarithmic regression of the temperature from self heating vs. the Solvita Index shows an $R^2 = 0.84$. There is a group of data values with Solvita Index between 7 and 8 and self heating up to 35 °C.




values are well scatted around the regression line. There is one outlier with the highest OUR, but showing only a Solvita Index of 3.

### *3.2.1. Self heating*

The temperature for the self heating varied from 22 °C (= room temperature > no self heating) up to 70 °C for younger piles up to 3 weeks old. As for the chemical parameters the variation between the samples from the same pile and age is higher for fresher ones, and lower for older samples. But still the variation is much lower compared to chemical parameters. Although the correlation is only $R^2 = 0.52$ for an exponential regression for self heating vs. the age (Fig. 9). Different factors apart from the age of the pile, for example the content and the treatment of the pile seem to be more important.

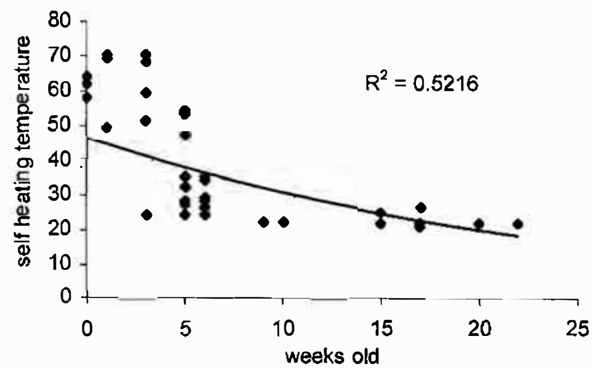


**Figure 9:** The self heating vs. the age of the sample shows a low correlation. But in general the older the sample, the lower the self heating.

For the comparison of the methods the maximal reached temperatures were used and not the official stability classes "Rottegrad". The self heating method shows high correlations vs. OUR ($R^2 = 0.921$), as well as vs. Solvita Index ($R^2 = 0.845$). But there is always a data cluster with low self heating. It's obvious that, if the sample reaches a stage without any self heating, it may be considered as stable. But for Bord Na Mona this is a very important point, to decide when the pile is ready for the production, and then the final use of the compost in the growing media. As soon the sample shows a self heating increase of less than 10 °C, the compost goes into the official compost stability class "Rottegrad" 5 with the description "very stable, well-aged compost". There is still the question to clear, if this stability stage is high enough for Bord Na Mona's application. But as the method always showed a good correlations with the other two methods, self heating could be a method to examine the composting process, especially in the first weeks.

The test doesn't need any maintenance or complex/ advanced instrumentation. The Dewar self heating test is very easy to handle, as the samples need only to be brought to the right moisture contents and to fill the vessels. The "Fausttest" are adequate for moisture control for this method. The control of the moisture content after completely drying in the oven showed clearly, that mostly the moisture content was between 55 and 60% or slightly above or below (data not shown). No further laboratory equipment is required, which makes the method very cheap. The limiting factor is only the number of vessels, thermometers and that it takes at least 5 days to get the results.

### *3.2.2. OxiTop*

The calculated respiration velocity of the OxiTop system varied for the 48 samples from 5 for old piles up to 116 mmol $O_2$/kgOS/h for very fresh piles. For 6 samples of those 48 samples the OUR couldn't be calculated. As a general trend, the younger the pile, the higher the OUR. But although the correlation for an exponential regression OUR vs. age of the piles is with an $R^2 = 0.59$ better than the correlation of the self heating, it is still poor. Other parameters as in 3.2.1. discussed could be more important, than the age itself. All the samples equal or older than 6 weeks have an OUR of 5 to 15 mmol $O_2$/kgOS/h. Veeken (2003) determined an OUR of 5 to 15 mmol $O_2$/kgOS/h as stable for biowaste or greenwaste. The OUR for the 6 weeks old samples are just around 15 mmol $O_2$/kgOS/h, so in fact these could also be defined as unstable (Veeken, 2003: unstable: OUR: 15 to 30 mmol $O_2$/kgOS/h).

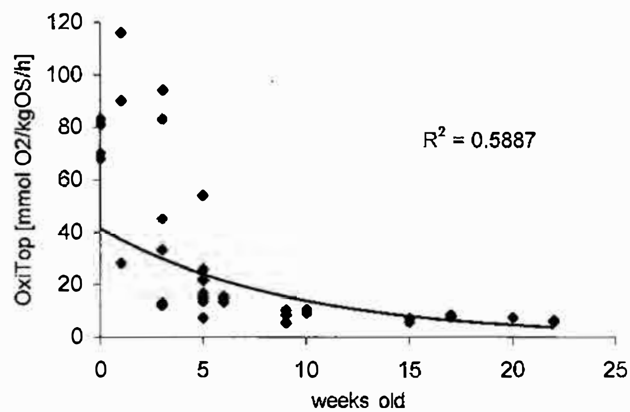



**Figure 10:** The OUR vs. the age of the compost samples shows a low correlation. The variation for OUR is quite high for fresh samples and decreases the older the piles get.

The comparison with the Solvita Index shows a slightly lower correlation of $R^2$ = 0.837 for a logarithmic regression and again a data cluster of samples with low OUR. Most of the samples show an OUR between 5 and 20 mmol $O_2$/kg OS/h.

The OxiTop method is easy to handle, but needs much more effort and time than the other methods to get the final result, as the exact moisture and ash content have to be determined. The data have to be transferred to the computer and the OUR needs to be calculated. So it takes 7 to 8 days to get the final results. Also there is the need of a few chemicals (buffer, nutrients), a shaker with thermostat and the measurement heads with the controller. The result is the highest acquisition costs of the three compared methods. Also an oven for moisture and one for ash have to be available. As the measurement heads are quite high acquisition costs, the number of heads is the limiting factor for the sampling. But if the acquisition is done (~ € 3000 for 6 measurement heads and controller), no further costs for the equipment are necessary.

In the measurement series, the limiting factor for the data collection was the low number of only 8 OxiTop heads. The measurement with the heads takes 5 days and one head is needed for the control. Due to a lack of time and because of the low number of measurement heads, it was not possible to do samples in duplicate or to repeat many samples. So reliance was placed on the correct, received OxiTop results. For the 6 samples, where a calculation of the OUR was not possible the most common problem was an increasing pressure drop without obvious reason after a normal pressure decrease first. This could be a possible leaky bottle. This problem could be solved very easy, doing the measurements in duplicate or by repeating the measurement, but the results are not available before a 5 day time period. This 5 or 6 days could already have an influence on very active samples and could change the result significantly. One sample was repeated twice, as there was a problem with the pressure drop in the middle of the measurement (So the first OUR wasn't absolutely reliable) and two samples$^{(*)}$ once (data not shown). The OUR came down from 68, 94$^{(*)}$ respectively 83$^{(*)}$ mmol $O_2$/kg OS/h (just after sampling), to 54, 81$^{(*)}$ respectively 78$^{(*)}$ mmol $O_2$/kg OS/h after one week, to only 14 mmol $O_2$/kg OS/h after two weeks time. Even if there are only three samples, there is variation and for one sample, a massive decrease of the OUR. Doubts may arise if samples are even repeated even after only one week, especially fresh ones. Another open question, that couldn't be answered is, how homogenous and reliable the OUR with OxiTop are within a sample, if it is done in replicates, since only 10 g of sample may be used. As the sample is only sieved < 10 mm there are plenty of particles in it with different sizes. Much more variation must be evident, than for example, with self heating were 2 l of sample are used.

Another problem, while using samples from very fresh piles, was that it was sometimes hardly possible to do a linear regression over a longer time period with the result from the OxiTop heads. The pressure drop was nowhere linear as described (Veeken, 2003), but exponential (Fig. 11). Only in a few cases a short period of linear decrease occurred, before it changed to an exponential decrease. Veeken (2003) describes, that a pressure difference between the maximum and the minimum values as 100 hPa (in the current tests that means a respiration velocity higher than 15 to 20 mmol O2/kgOS/h) could be a critical limit, where the oxygen could be rate limiting by depletion of the gas phase. To have any data for very young piles, the highest OUR was determined in those special cases and this value was used solely, since repetition or modification wasn't possible due to lack of time. The OUR decreased in those samples from the beginning (Fig. 12); here limitation factors other than the degradation rate may be evident, with perhaps $O_2$ limitation in the liquid phase. Veeken (2003) recommends for those special cases, to repeat the measurement with a reduced volume of sample, thus reducing the amount of organic matter from 3 g down to 2 or 1 g; effectively a system of trial and error. Because this

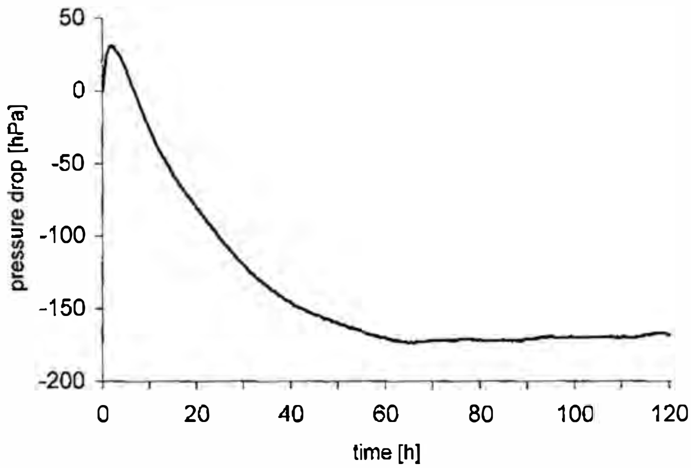



**Figure 11:** A typical exponential pressure drop in time for a very fresh and active sample in OxiTop, which makes it hardly impossible do fit a linear regression in it.

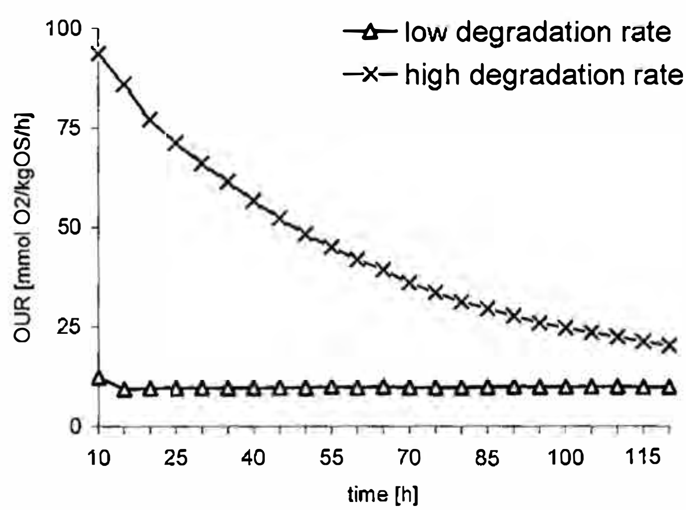



**Figure 12:** For sample with a low degradation rate the pressure decreases linear as described by Veeken (2003). The result is a constant OUR over the whole time period. For samples from very young piles with a high degradation rate the OUR decreases from the beginning.

problem happens especially with fresh samples, major concerns arise when repeating the test after one week. There could be a big variation in the resulting OUR. In this study two samples were repeated (with a reduction of organic matter from 3 g to 1.5 g) that showed an exponential pressure decrease with the half amount of sample (data not shown). The determined OUR were for both samples the same for 3 g or 1.5 g of organic matter. So the reduction in amount of organic matter didn't solve the problem at all. The decrease was still exponential. It seems to be quite difficult to determine an amount of organic sample, where the pressure drop is still linear but also still clear enough to do a regression.
It would therefore appear necessary to do first some other tests to determine the stability stage of the sample.

As the OxiTop method seems to be quite sensitive and reaches a good conclusions on the state of the composting process, it should be possible to determine validation criteria for the compost stability/ maturity dependant on the final use of the compost. An open question is the variation of the OUR within one sample, to determine if the method is really more sensitive/ reliable than self heating.

### *3.2.3. Solvita® Compost Respiration Test*

The Solvita Index varied for the different samples from 1 (fresh, raw compost) to 7 (well matured, aged compost). The test shows a poor correlation with the age of the samples (Fig. 13) and the highest variety with Solvita Indexes of 4 (= compost in medium or moderately active stage) to 7 (= well matured, aged compost) for older samples (≥ 9 weeks). Compared with the other two systems the correlation is significant with $R^2$ = 0.84, but the test shows the lowest correlation of all three methods. If the Solvita $CO_2$ result is compared with ($CO_2$ number from detector with 2 places

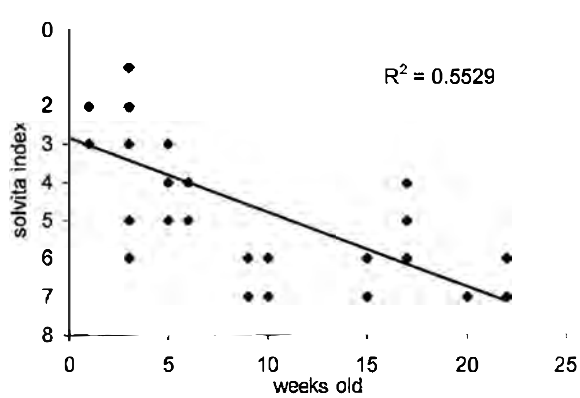



**Figure 13:** The Solvita Index vs. the age of the piles shows a low correlation for the linear regression. But in general the Solvita Index increases, the older the piles get.

behinds the coma, see data appendix) with the other two methods an increased correlation of $R^2$ = 0.87 for self heating and $R^2$ = 0.85 for OUR occurs.
The values for the ammonia paddles were mostly slightly below 5, but for $CO_2$ values between 1 and 7 were recorded. For ammonia values of 4 to 5, the Solvita Index is the same as the $CO_2$ value.

The Solvita test is very easy to handle and very quick, without the requirement of any laboratory equipment. However, each sample costs around € 35. A large number of samples can be done, as the only limiting factor is the amount of jars and paddles. The detector to read the paddle was helpful as the colour was sometimes hard to compare with the colour chart. Especially with the $NH_3$ paddle it was sometimes impossible to distinguish the difference between 4 and 5 without the detector. However, in the current test series this influence on the final Solvita Index would be minimal, as the test is not too sensitive.
The test doesn't give too much information and is quite expensive for the resulting information content. As it's a relative test, it can't replace respiration measurements completely or the determination of the ammonia concentration in the laboratory. But it gives a short overview and a useful application of the test could be on-site.

# 4. CONCLUSIONS

The Solvita test, although with a with the quite good correlation to the other procedures, delivers less information and gives much higher variation for older samples. Thus this method should only be used if a quick and raw overview over the stability is needed.

The self heating reaches in comparison with the other methods the highest correlation and is easy to prepare and very cheap. But it's hardly possible to determine stability of very stable samples.

The correlation of OxiTop against the other methods is only slightly lower than for self heating. But the results show much more details. Moisture and ash content (that often have to be done anyway) with this method gives further useful information about the samples. However, the use of the OxiTop system for very fresh piles needs more time, care and attention to detail, as for the more matured samples. So, to determine the compost stage of fresh samples, self heating is perhaps a better method than OxiTop. The OxiTop system showed in these studies a lot of open questions such as reliability within replications. The most problems happened, while using fresh piles. If OxiTop is solely used to determine the final stability, this problem doesn't occur. But still the question of the variation within the same sample has to be solved and for Bord Na Mona it has to be determined, which stage of stability is required for the further use of the compost.

If the stability stage with low self heating is sufficient, the self heating method could be sufficient. But if a higher stability is needed, further test with the OxiTop system should be done to answer the open question.

Notwithstanding the results and the knowledge available for the OxiTop, the self heating method seems to be the most efficient, time saving and cheapest method. Thus this method may be recommended, at least till the open questions for the OxiTop are solved.

### Further steps

For final determination of the best stability method for Bord Na Mona to determine if the compost is mature enough for the production, the following questions have to be answered:

- Which stability stage is needed for the growing media production?
- Which self heating / OxiTop results represent this stability stage?
- What's the variation and consistency of the OxiTop results within the same samples?

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**Tab. 2:** All the used data for the method comparison.

| | Pile | pH | EC | NH4 | CO2 | Solvita Index | max. Temp . | Rotte-grad | Oxitop | weeks old | C:N ratio | NH4N: NO3N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A57 | 4.49 | 1411 | 4.09 | 0.94 | 1 | 62 | 1 | 81 | 0 | 13 | 0.9 |
| 2 | A57 | 6.06 | 1061 | 4.17 | 0.8 | 1 | 64 | 1 | 70 | 0 | 11 | 1.8 |
| 3 | A57 | 6.93 | 834 | 4.21 | 1.37 | 1 | 62 | 1 | 83 | 0 | 14 | 0.3 |
| 4 | A57 | 6.2 | 718 | 4.1 | 2.03 | 2 | 58 | 2 | 68 | 0 | 10 | 4.6 |
| 5 | A56a | 8.18 | 1719 | 3.79 | 2.21 | 2 | 70 | 1 | 90 | 1 | 11 | 50.2 |
| 6 | A56a | 7.95 | 2400 | 3.89 | 2.52 | 3 | 69 | 1 | 116 | 1 | 13 | 49.9 |
| 7 | A56a | 7.77 | 1095 | 4.18 | 3.49 | 3 | 49 | 3 | 28 | 1 | 11 | 31.9 |
| 8 | A56a | 7.73 | 1188 | 4.49 | 2.21 | 2 | 59 | 2 | 45 | 3 | 15 | 0.0 |
| 9 | A56a | 6.16 | 1775 | 4.76 | 0.8 | 1 | 68 | 1 | 94 | 3 | 12 | 6.6 |
| 10 | A56a | 6.42 | 2290 | 4.7 | 0.8 | 1 | 70 | 1 | 83 | 3 | 15 | 5.4 |
| 11 | A56a | 8.09 | 1084 | 4.81 | 2.89 | 3 | 51 | 2 | 33 | 3 | 13 | 9.6 |
| 12 | A56a | 8.40 | 1566 | 4.55 | 6.28 | 6 | 24 | 5 | 12 | 3 | 10 | 38.9 |
| 13 | A56a | 7.52 | 779 | 4.84 | 5.4 | 5 | 24 | 5 | 13 | 3 | 14 | 6.0 |
| 14 | A55 | 6.80 | 1152 | 4.92 | 2.59 | 3 | 54 | 2 | 54 | 5 | 12 | 2.3 |
| 15 | A55 | 7.22 | 2700 | 4.92 | 3.18 | 3 | 47 | 3 | 22 | 5 | 21 | 1.2 |
| 16 | A55 | 6.88 | 646 | 5.14 | 4.43 | 4 | 32 | 4 | 17 | 5 | 12 | 0.0 |
| 17 | A55 | 7.13 | 944 | 4.97 | 3.04 | 3 | 53 | 2 | 26 | 5 | 11 | **3.4** |
| 18 | A55 | 7.30 | 827 | 4.91 | 4.60 | 5 | 28 | 5 | 15 | 5 | 13 | 1.2 |
| 19 | A55 | 6.96 | 743 | 4.82 | 3.69 | 4 | 35 | 4 | 16 | 5 | 13 | 0.0 |
| 20 | A55 | 6.40 | 606 | 4.84 | 3.91 | 4 | 32 | 4 | 22 | 5 | 11 | 1.3 |
| 21 | A48 | 8.00 | 766 | 4.88 | 5.45 | 5 | 27 | 5 | 14 | 5 | 12 | 11.8 |
| 22 | A48 | 7.30 | 1039 | 4.93 | 5.14 | 5 | 24 | 5 | 7 | 5 | 11 | 0.2 |
| 23 | A46 | 7.70 | 837 | 4.83 | 3.84 | 4 | 35 | 4 | | 6 | 13 | 0.6 |
| 24 | A46 | 8.20 | 1282 | 4.85 | 4.67 | 5 | 29 | 5 | 15 | 6 | 12 | 34.9 |
| 25 | A46 | 8.42 | 1138 | 4.86 | 4.60 | 5 | 34 | 4 | 15 | 6 | 11 | 34.6 |
| 26 | A47 | 8.16 | 777 | 4.92 | 4.97 | 5 | 24 | 5 | 15 | 6 | 10 | 36.1 |
| 27 | A47 | 7.40 | 752 | 4.88 | 4.43 | 4 | 28 | 5 | 15 | 6 | 10 | 27.3 |
| 28 | A47 | 6.96 | 525 | 5.04 | 4.12 | 4 | 26 | 5 | 13 | 6 | 11 | 20.8 |
| 29 | A43/44 | 7.94 | 548 | 4.79 | 6.05 | 6 | 22 | 5 | 10 | 9 | 10 | 5.0 |
| 30 | A43/44 | 7.76 | 684 | 5.03 | 6.82 | 7 | **22** | 5 | 8 | 9 | 13 | 0.1 |
| 31 | A43/44 | 7.33 | 808 | 4.84 | 6.76 | 7 | 22 | 5 | 5 | 9 | 11 | 0.6 |
| 32 | A41/42 | 7.30 | 1196 | 4.76 | 6.05 | 6 | 22 | 5 | 10 | 10 | 11 | 0.8 |
| 33 | A41/42 | 7.52 | 875 | 4.79 | 6.76 | 7 | 22 | 5 | 10 | 10 | 11 | 0.2 |
| 34 | A41/42 | 7.31 | 1092 | 4.87 | 6.23 | 6 | 22 | 5 | 9 | 10 | 11 | 0.2 |
| 35 | A34/35/36 | 7.30 | 1609 | 4.92 | 6.58 | 7 | 25 | 5 | 6 | 15 | 10 | 8.1 |
| 36 | A34/35/36 | 7.08 | 1225 | 4.98 | 6.28 | 6 | 22 | 5 | 7 | 15 | 11 | 9.4 |
| 37 | A33/34 | 7.39 | 1175 | 4.78 | 3.91 | 4 | 22 | 5 | 8 | 17 | 13 | 4.4 |
| 38 | A33/34 | 7.82 | 1136 | 4.77 | 4.67 | 5 | 22 | 5 | 8 | 17 | 11 | 11.1 |
| 39 | A33/34 | 8.07 | 1145 | 4.84 | 5.53 | 6 | 26 | 5 | 8 | 17 | 11 | 16.6 |
| 40 | A31/32 | 6.35 | 1454 | 4.96 | 6.82 | 7 | 22 | 5 | 7 | 20 | 12 | 3.1 |
| 41 | A31/32 | 6.27 | 1216 | 4.87 | 6.87 | | 22 | 5 | | 20 | | 1.5 |
| 42 | A31/32 | 6.34 | 1048 | 4.92 | 6.69 | 7 | 22 | 5 | | 20 | | |
| 43 | A29/30 | 6.33 | 1670 | 4.92 | 6.23 | 6 | 22 | 5 | 6 | 22 | 12 | 8.7 |
| 44 | A29/30 | 5.94 | 1096 | 4.98 | 6.78 | 7 | 22 | 5 | | 22 | 10 | 1.1 |
| 45 | A29/30 | 6.25 | 1288 | 4.89 | 6.54 | 7 | 22 | 5 | | 22 | 11 | 8.5 |
| 46 | A28 | 6.00 | 1060 | 4.78 | 6.58 | 6 | 22 | 5 | | 22 | 11 | 2.3 |
| 47 | A28 | 5.82 | 792 | 4.77 | 6.23 | 6 | 22 | 5 | 6 | 22 | 17 | 0.3 |
| 48 | A28 | 6.23 | 550 | 4.84 | 6.09 | 6 | 22 | 5 | 6 | 22 | 12 | 0.6 |

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(Woods End donated the Digital Equipment for the Study)

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| 1) Only 3g sample was employed for Oxitop instead of the normal 25-100g. The soil/compost Oxitop kit is not the tall narrow BOD jar shown but a low one that holds up to 200g compost. |
| 2) It appears that aged samples were stored differently and at room temperature and dried before using. |
| 3) The source of Dewar vessels should be noted. A QC check for heat loss should be performed. The flasks are 2-liter instead of the normal 1-liter flask size as specified in the Bundesgutegemeinschaft Kompost method. |
| 4) It is not clear how the cost per test of 35 EURO for Solvita was arrived at. In the USA it is $12-15/test (10-12 Euro) and in the EU the highest observed cost is about 25 Euro test. |
| 5) The observed variability over age with Solvita and Dewar where compost density increases and is not accounted for in filling the flasks/jars . This could influence the observed effects. |
| 6) There is a loss of information by rounding the Solvita DCR CO2 values to whole integers as used the manual Maturity Index (the color chart system). It is not clear why the authors do this since unless the DCR was not used. |
| 7) The Study correlates a) each test method with compost age and b) each method with each other; however there is no independent validation of maturity with the compost properties measured. |
| 8) The study uses Oxitop as in the manner of a BOD test with added nutrients, but none of the other tests have added nutrients; this may have affected results. |
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