Aerated composting. A silent practical breakthrough.

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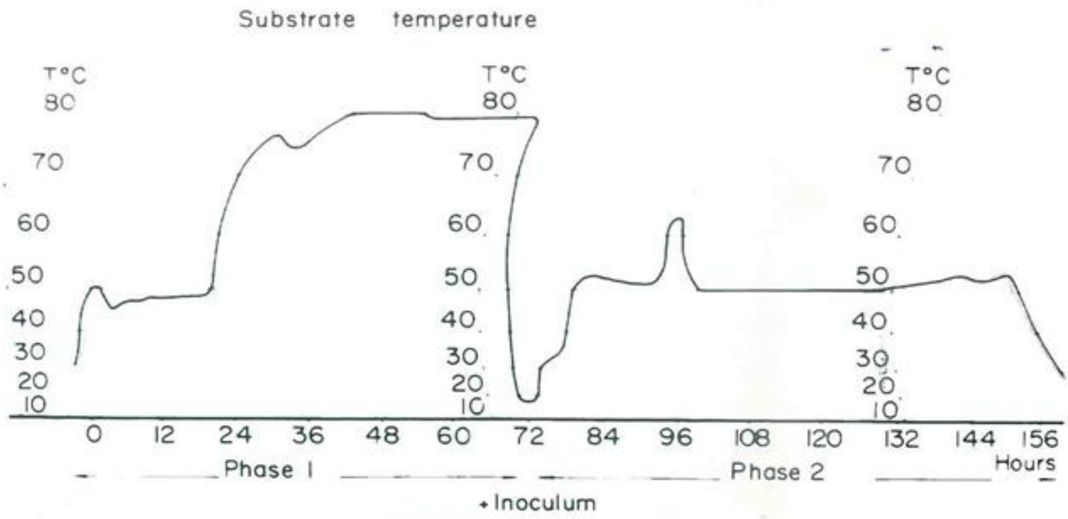
Abstract:
This paper is a summary of experiences and observations at many different composting yards in Europe, Middle East and Japan with aerated composting for *Agaricus bisporus* since 1976. The process of balancing between increasing temperatures and absorbing water.
The practical importance of forming brown substances by Maillard reactions is expressed.
Explaining the sequence of algae, th. fungi, th. bacteria, oxidations at Maillard reactions and chemical reactions at specific temperature ranges with the effect on selectivity and structure.
The present opinion of optimal figures of pH value, moisture content, NH_4 content, Nitrogen content, ash content and C/N ratio at the moment of spawning are evaluated.
The relevant pattern of on/off settings at different temperature levels will be described in this paper.

Keywords:, heating, temp. sequence, Maillard reactions, protective coating, selectivity.

Sections:

1. Introduction.

The great inspirers in research of aerated composting in Europe were Mr. Jean Laborde and Mr. Alex Oversteyns. The first modern system of aerated composting was carried out at Kuhn, Full in Switzerland (Indoor Static Composting) at February 1987 and is still in operation. The main technical breakthrough was at Tolson's, Australia in 1992 a new type of bunker with a spigot floor and in Europe at Walkro Belgium in October 1993 with an open aerated spigot floor and a conveyor belt on top. C.N.C at Moerdijk NL. started in April 1995 with an unique Phase I system in tunnels and an industrial pre wetting factory. Afterwards mainly concrete bunkers with spigot floors and an on/off aeration system were build, filled by bunker fillers or overhead conveyor systems for filling in layers.



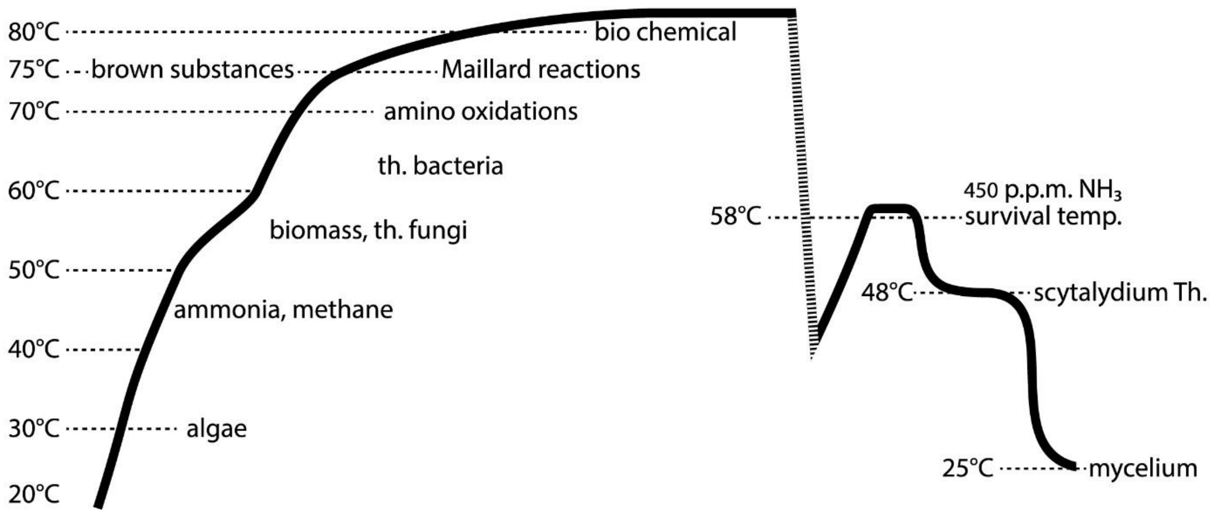
(After Laborde et al , 1989)

Mr. Jean labored was in favor of high temp. but also a few days of aerobic pre wetting at 45^0 C. for creating a firm biomass, mainly important for straw composts and not for horse manure At this moment aerated composting is **the** common solution for producing more stable Phase I composts on a smaller area with less odor problems. The type of compost did in general not change much since 50 years but the structure improved by more homogeneous, less greasy, less over fermented composts. This is important for better results at peak-heating in tunnels and consequently at incubation and cropping.

2. Temperature sequence.

For a consistently high yielding substrate a high temperature Phase I seems to be required and thermal destruction of microbial populations is an essential part of the succession process. The nitrogenous complex with brown substances forms a protective coating around the remaining carbohydrates, like cellulose and hemi-cellulose. This limits their utilization by competitor molds. The enzymes of *A. bisporus* mycelium have the possibility to degrade such a coating and creates access to the underlying nutrients by the production of hydrogen peroxide and oxalic acid.

Table 1.



*< 50^0 C. At the first heating, ammonia plays an important role in destroying the cutine layer of the straw as the first opening. Adding urea or sulfate of ammonia in an early stage does accelerate this process. Ammonia softens the straw chemically, making more organic matter available for converting nitrogen in other more complex forms.

The first start, being loose water in the matrix, is a more anaerobic process of methanogenic bacteria and methane-gas production accompanied with mal-odor. This can be reduced by several flips and adding not too much water at the start. This part takes much oxygen.

* Between 50^0 and 60^0 C. The further thermophilic biomass composed of fungi, bacteria and yeasts increases rapidly and converts easy degradable carbohydrates into sugars, proteins, CO_2, ammonia and amino-acids. This part seems very important to build a firm biomass. It could be positive to have a not very fast temp. increase at this stage.

* Micro biotical activity in composting at temp. under 65^0 C. do burn more organic material and it mainly reduces the available excess of nutrition and also can have a negative effect on a more soft structure. At temp. over 65^0 C. the heating process is mainly conducted by Th. bacteria and does take less oxygen.
Typical brown substances are formed between 70^0 and 80^0 C. in the presence of ammonia. The change in darkening of the straw is important for the nutrient availability for *A. bisporus* besides the more stabilized selectivity.
* From 70^0 till 75^0 C. mainly a biological process by creating polyphenols out of therm. fungi, using soluble sugars and starch. Forming brown substances completed with lignin degradation by enzymatic reactions and amino oxidations. These reactions do integrate Nitrogen and protect it.
* Over 75^0 till 80^0 C. more formation of brown protective substances by bio-chemical activity (Maillard-reactions). Production of caramellanoidins from sugars and amino-acids by which nitrogen products are protected to many molds. Giving a compost at emptying a bunker a specific caramellious smell.

3. Optimal figures.
Apart from visional inspection of a compost at the moment of spawning you need to have time by time reliable chemical analyses. Herewith some general average figures:
*pH-value 7.3, which is lower by the use of sulfate of ammonia at Phase I. Goal is pH 6.2 after 15 days of spawn-running.
* NH_4 or ammonium content 0,02 %. High pH combined with high NH_4 is negative.
* Moisture content 68 %, Always related to the structure. In general never water is added at spawning but always at filling Phase I compost in tunnels. Optimal 63 % of Phase III.
* Nitrogen content dry material 2,1 % for horse manure composts and 2,2 % for straw composts.
* Ash content about 25 % to have sufficient organic material and not too much pollution by silicates, sand or other not producing minerals.
* C/N-ratio dry material 17 with which there are empirically the best yields.

Besides just figures, mainly the structure of the compost is very important for an optimal yielding capacity. It is hard to bring structure into figures, the same like color and smell. There are some quality monitoring procedures in use to give a figure at certain stages of the preparation of compost for color, structure and smell.
Compost can be too homogeneous. In the past in the traditional rick system, mixing and more mixing was necessary to create more homogeneity and many times the result was poor. Nowadays with the modern mixing stations in combination with aerated composting in bunkers too much homogeneity can be created and a soft, sticky compost can be the result.
I have the opinion that some parts of less degraded straw can create a framework and give more volume of the Phase III compost.
This results in more activity and temp. difference at growing and a better temp. increase at the end of the first flush. Even if these less fermented straw-parts do not contribute to the direct

nutrition of the mushroom. A strong general opinion is also that over fermentation is much more negative than under composting.

Gypsum is a very important ingredient of the compost. Without gypsum no mushrooms.
In can be from a natural source or a byproduct of a clean industrial process. It reduces the pH at Phase I and II and neutralizes the oxalic acid formed by the *Agaricus* mycelium at incubation and later during cropping. Only Ca $SO_4.2H_2O$ (dihydrate) is suited and Ca SO_4 0 H_2O (anhydrite) is not. Calcium carbonate ($CaCO_3$) can just be used in combination with sulfate of ammonia by which chemically gypsum will be formed.

4. Practical.
Temperature increase seems by far the most important item in aerated composting. After filling the bunker, at day 0, the temp. should reach 80 ^{0} C. in about 12 hrs. Therefore also at pre wetting, outside or in a bunker, the last day before filling the bunker, the temp. should be at least 75^0 C. to give a good start of Phase I at day 0, means one week before filling the tunnel.
The process of fermentation is basically a **balance** between absorbing water and increasing temperatures. The first watering of the straw should not create anaerobic conditions but an temp. increase. This temp. increase, at ammoniatical conditions, creates softening of the straw. This dewaxing creates more absorption and makes other carbohydrates free for heating activity. This creates brown substances by so called Maillard-reactions and more softening and burning carbohydrates for activity. By more watering at high temp. the chemical reactions at 80^0 C. take place to create a chemical burning effect without losing structure in order to make a not greasy dark compost every week. In this respect composting means burning carbohydrates at aerobic conditions and for this in every step not too much water should be added. Because it is difficult to give water for more than 2 days in advance and if the straw is opened after high temp. than in a later stage more water can be absorbed.
Measuring the oxygen content in the compost fails in practice regularly and it can be used to find the optimal timer settings in order to get an optimal temp. increase towards 80^0 C.
This because an optimal temperature increase is always a sign for optimal aeration.

Here follows a general insight of different optimal oxygen levels.

	Part one	Part two	Part three
	Start till 65^o C.	65^{o}C till 75^{o}C.	75^{o}C till evt. higher
Oxygen in compost	10 %	Min. oxygen 9 %	Min. oxygen 8%
Need for fresh-air	10 m^3 /ton/hr.	7-8 m^3 /ton/hr.	3-4 m^3 /ton/hr.
Possible setting	20 min on	15 min on	4 min on
	10 min off	15 min off	16 min off

Calculating fan capacity for 300 tons. 300x8 = 2400 m^3/hr. times 2 = 4800 m^3/hr for 15 on and 15 off. Air pressure at least 3000 Pascal. For 30 tons it is 10 % of this fan capacity.

In closed bunkers it is important to ventilate above the compost in order to reduce the temperature lower than 50^0 C. and create the survival of *Scytalidium th.*

After emptying the bunker it is wise to leave the compost outside for 12 hrs. before filling the tunnel in order to regenerate the micro flora.
In periods of difficult clearing of ammonia it can also be advisable to mix about 2 % Phase II compost at filling the tunnel with Phase I compost as bio inoculum. An ongoing discussion is also what to do when the compost is free of ammonia at the end of condition. Or wait till spawning at conditioning temp. or cool down to 28^0 C. In my opinion it is best to cool down and not burn more carbohydrates than necessary.
Goal is to produce week by week a black and not greasy type of compost, which can be finished well at peak heating. The ammonia, NH_3-reading at the end of pasteurization, plays a more important role in this than the nitrogen content. By giving more or less ammonia in the form about 10 kg. of poultry manure, or about 1 kg. of sulfate of ammonia or about 40 ltr. of goody water per ton of compost at the end of fermentation or filling the tunnel, the level can be changed. This in order to calibrate the ammonia-level at the end of pasteurizing at an optimal figure of 400 till 500 ppm for creating more selectivity against weed molds.

Conclusion.

Though conflicting discussions between rival camps of scientists in the eighties till early 1992 regarding low temp. fermentation against high temp. aerobic fermentation were carried out. Different practical composters proved conclusively the supremacy of high temp. aerobic fermentation by the use of bunkers with spigot floors. Since Mr. Jean Laborde did set the puzzle together is composting less scientific. With a good pre wetting, by intensive mixing of the ingredients and a mechanical shredding of the straw, this system can successfully be used in big and small operations all over the world. Goals is to produce week after week a dark brown and not greasy type of compost. For this a period of low temp. for creating biomass and also a period of high temp. for browning is necessary. Do understand that for horse manure the low temp. period did last 14 days at the stables and for collecting. So in my opinion for straw composts it is better to pre wet at low temp. for a couple of days before going to high temp.

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