Sustainability of Modern Composting

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Intensification Versus Costs & Quality

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Introduction

Composting has traditionally been used as a form of slow rotting of farm-yard manures and vegetative wastes with the resultant humus product useful in agriculture (Balfour; Howard; Wistinghausen & Sattler). However, renewed interest and modern engineering involvement has resulted in an essentially new composting image emphasizing significant technological inputs (Hoitink & Keener, Biocycle; Rynk). A typical example is the use of frequent turning or forced aeration to deliver air constantly to a compost pile. Along with this intensification, there has naturally been a dramatic upturn in commercially available turning machines, in-vessel compost reactors, aeration systems, pile covers, and so on for farms, municipalities and industry. Finally, it is also apparent that there is increased availability to the consumer of a variety of compost-based products.

Despite this impressive record of modern composting, little if any actual studies or data exist comparing technology inputs either on the basis of cost/benefit or quality-of-end products. In contrast, within agriculture in general and specifically in organic and biodynamic farming, numerous comparison studies exist for various alternative management schemes from the viewpoint of cost/benefit, soil-degradation and quality of end-products (Lockeretz). From this point of view, the science of composting appears to lag behind technological developments. Furthermore, the sustainability of intensified composting has never been evaluated. This paper examines certain basic intensification assumptions in modern composting on the basis of economics and process biology. Under consideration is what the effects of varying intensification are in view of nutrient and organic matter retention, end-product quality and overall costs.

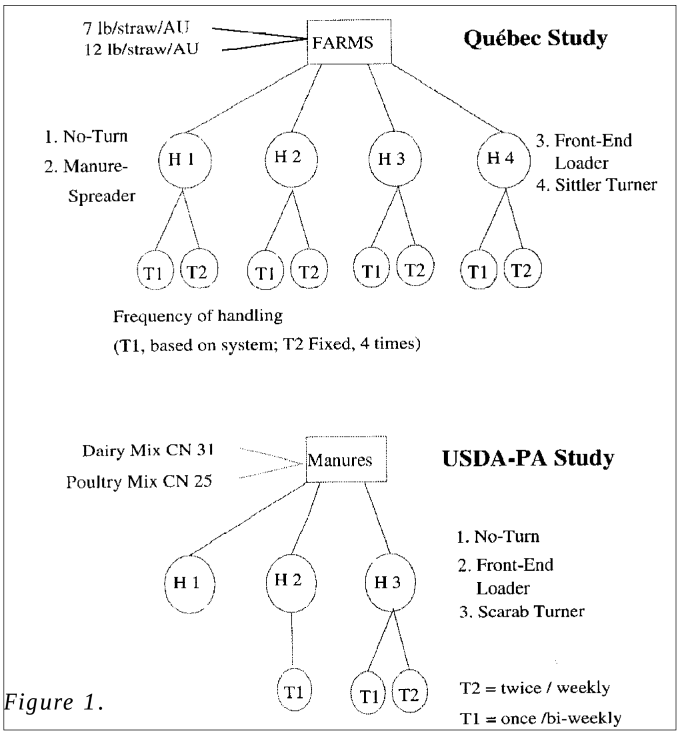

Figure 1.

Background: Sociology of New Technologies

It has been said that composting has achieved *paradigm* status and become a trend. It is suddenly an industry which has attained self-definition, and in this lie certain dangers. Constraining the examination of the merits of high-tech composting are the facts that the economics are curiously skewed, and in many cases waste products involve fees up-front (to the farmers or composters), called tipping-fees, before any actual sales of completed end-product take place. In Switzerland, for example, community tip fees to eligible farmers for contracted leaf and yardwaste composting are about SFr120 per tonne (Oltern Conf), while the potential value to the farmers may be more likely SFr 10-20/tonne (Wädenswil). Similarly, in the US while tip fees are not so high, it is possible to receive on the front end more than twice the value of the actual product. These factors translate into incentives representing society's desire to rid itself of the waste; they say nothing however about the intrinsic merit or sustainability of the current composting technologies chosen. Similarly, environmental pressure which may force growers to adopt composting does not necessarily translate into economical or viable practices.

The Farm View of Composting

Sustainability and quality are the key traits in the acceptance of composting within agriculture. There has been continued hesitancy on the part of farmers to

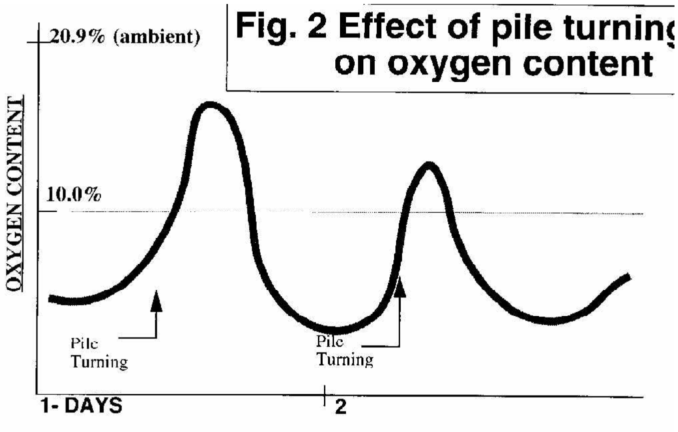

Figure 2.

adopt what appear to be machine-intensive, time-consuming composting practices. Farmers are, however, concerned about soil and water quality, and have demonstrated a commitment to improvements in waste management, with composting high on their list of interesting subjects. Additionally, organic and biodynamic farmers depend largely on recycled and composted local and on-farm resources for a fertilty base. As such, the growers are caught in a unique conflict. On the one hand they have their own needs and capabilities, the latter largely defined by cost and certified or eligible practices. On the other hand, they face a confrontational environmental sector combined with the alluring, high-tech pitch of the composting industry. Thus, a need exists to develop an agriculturally viable form of composting that is consonant with the traditional farm setting without sacrificing quality and viability.

Current Studies

Woods End Research Laboratory has been researching compost biology and use in farming over a period of many years. In this direction two research projects were funded to examine intensification of composting in relation to cost and quality of end-products. The first study was a joint project of Woods End of Maine and CDAQ (Centre de developpement d'agrobiologie du Quebec), funded by Agriculture Canada (Jobin, 1992); the second was conducted by Woods End with assistance of the Erth-Rite Company of Gap, PA and support of the USDA Technical Center in Chester PA (USDA, 1993). These two projects focused in on farm handling and its impact on the composting process.

The overall strategy behind the focus for these studies was examining the premise of intensification, and its impact. To develop composting within agriculture the following goals are seen as operant:

- Limit necessary source material to local or on-farm resources;
- Identify and focus on key traits for composting and eliminate unnecessary technology steps;
- Test approach in varying farm settings including Quebec Dairy Farms (Agriculture Canada) employing varying amounts of straw bedding and on Pennsylvania Dairy and Poultry Operations (U.S.D.A.)

The composting studies assembled two groups of ingredients varying from straw to sawdust for bulking and subjected them to a range of intensification scenarios from no-turning to high-rate Scarab-type turning, as follows:

Table 1: Treatment Structure of Compost Intensification Studies

Quebec Dairy	PA Dairy/Poultry
Bedding Materials Key: Low vs. High Straw Farms	 Straw vs. Sawdust mixes Dairy + Beef with Straw Poultry with Sawdust
4- handling methods: - low-cost Sittler turner - bucket loader - manure spreader - dump-wagon, no turn	3-handling methods - Self-propelled turner - Bucket loader - No turning

Lay-out of Treatments

Figure 1 depicts the structure of treatments and sub-treatments for the studies (previous page). In the first study we varied the frequency of turning based on recommended approaches (T1) versus fixed approaches (T2) with two farms having varied ratios of straw to manure, influencing the porosity of the mix. In the second study, we varied manure type and carbon source with 3 types of turning.

Treatments were replicated twice or three times, each for the USDA and Quebec studies, respectively. The study collected information throughout the process on:

- temperature & oxygen performance
- organic matter and nitrogen loss
- change in humification and respiration rate
- O & M (operations/maintenance costs)

In this report we give data for temperature, oxygen and organic and nitrogen matter losses.

RESULTS

Compost piles are normally turned in order to reintroduce oxygen, which is necessary for aerobic composting. In the first part of these studies, we examine the immediate effects of turning by measuring oxygen content 2.5ft within the compost pile before, during and after turning by a windrow machine. The results of observing these effects over two days are seen in Figure 2.

The effect of pile turning was to refresh oxygen content, on average for 1.5 hours (above the 10% level) after which it dropped to less than 5% and in most cases to 2% during the active phase of composting. No significant differences were observed between windrow turning machines and manure-spreader turning, while bucket loader turned piles depended more on operator efficiency as to how much temporal air was introduced.

We have previously reported temporal oxygen effects of turning. However, we have also shown that they exert little or no negative effects if aerobic activity in the long term is the issue (USAEC, 1994). As later data will show, it depends on pile size and porosity. By introducing more straw which we do in the Quebec study, the effects are similar to introducing more air (Fig.4).

We also observed that self-aeration in these compost trials appeared to exert a significant overall effect. The graph (Figure 3) shows the three USDA turning treatments in relation to the behavior of oxygen content during the course of composting. Even with no turning, all piles eventually resolve their oxygen tension as maturity approaches, indicating self-aeration alone can adequately furnish the composting process.

The data shows that rapid high-rate turning with a turning machine advanced the final rise in oxygen (= stabilization) by a few weeks. However, all piles remained low in oxygen through-out the active composting period, and rose dramatically towards the end of their own accord. Contrary to how some would interpret this data, it proves that the piles are constantly consuming oxygen, and therefore remaining essentially aerobic despite low measured O_2 levels. In other words, turning the piles has a temporal but little sustained influence on oxygen levels. However, turning does rehomogenize the materials leading to an improved appearance.

We examine the length of time to attain stability defined as the point where pile temperature drops below 100F and does not rise even with turning. Figure 4 summarizes the results by presenting the two most extreme treatments for each experimental situation, respectively, for the Turning Intensity trials (PA) and Straw-Bedding Trials (Quebec study).

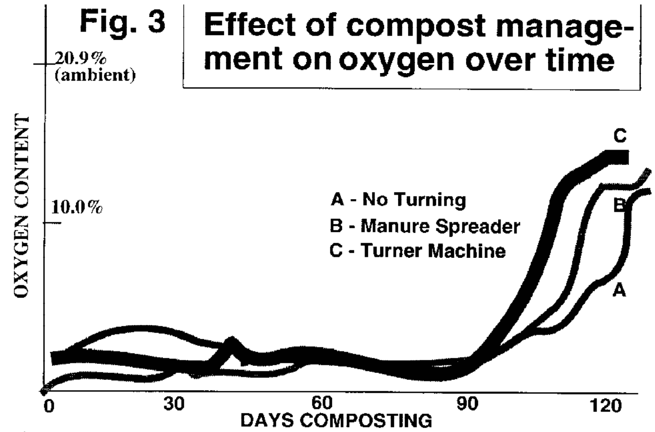

Figure 3.

The results clearly indicate that on the basis of temperature stabilization alone, intensification of the composting process either by more turning or adding more bedding had comparable effects of measurable but slight improvement in the time-efficiency for composting. In both trials, the mean maximum gain in time to stability from intensification was about 20 days; in the dairy manure compost trials, the time to stability of No-turned was 123 days versus 106 days with twice-weekly Scarab[1] -turned piles; and with the poultry manure compost trials the times were, 145 days vs. 130, respectively.

In order to more precisely measure stabilization, we applied the Dewar self-heating test on all piles at 120 days (Brinton et al., 1995). This information is reported in Table 2. We measure self-heating at one point for the dairy and at three points for the poultry which took longer to stabilize. The data show an advantage to intensive Scarab-turning of piles for poultry manure at

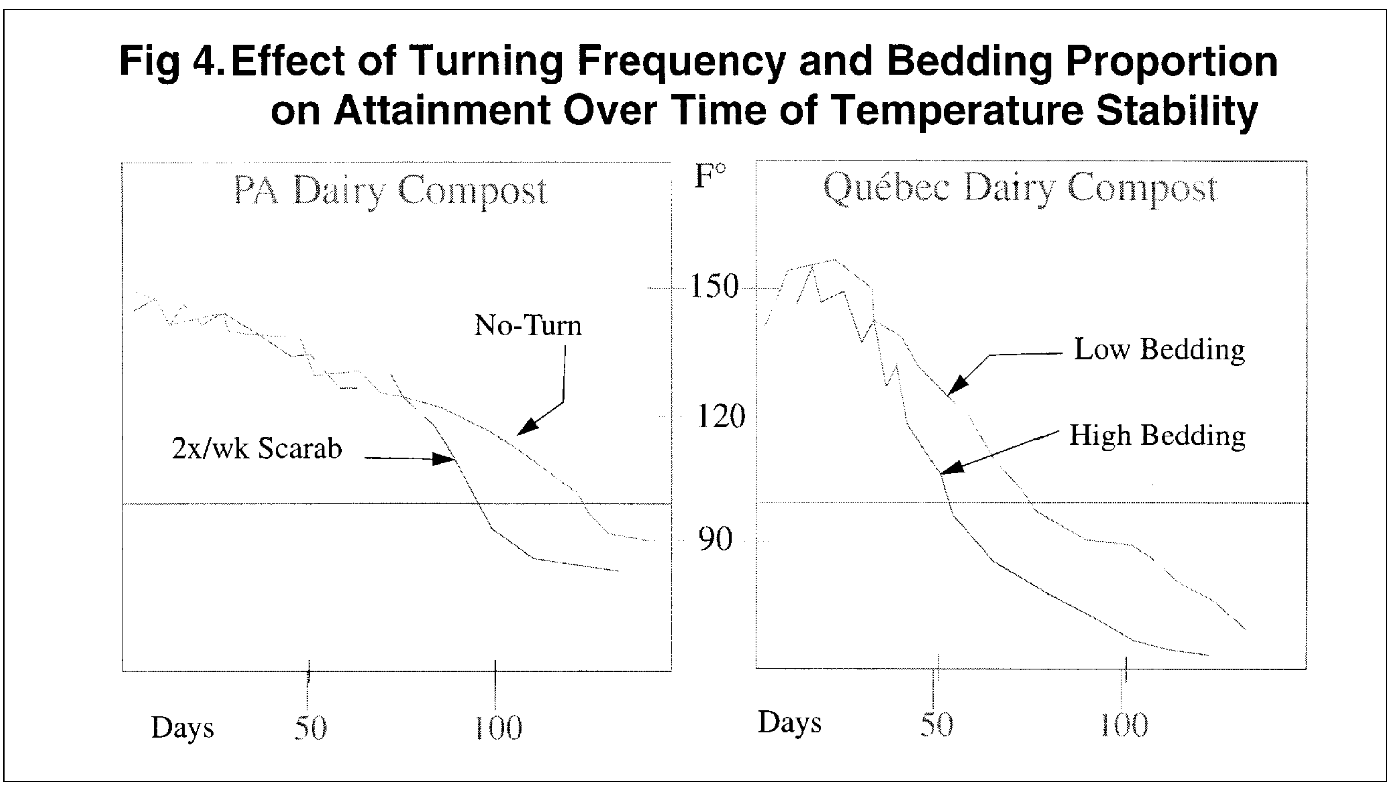

Figure 4.

Dewar Self-Heating (Maturity) of Compost in Relationship to Intensification		
TREATMENT	Age, (Days) Sampled	Temp Rise, C° above Ambient
Cow Manure Composts		
No-Turn	117	2
Bucket-Turned	117	3
Turner 1x/ 2 weeks	117	0
Turner 2x/ week	117	1
Poultry Manure Composts		
No-Turn	108	17
Bucket-Turned	108	16
Turner 1x/ 2 weeks	108	12
Turner 2x/ week	108	2
Poultry Manure Composts		
No-Turn	138	4
Bucket-Turned	138	9
Turner 1x/ 2 weeks	138	—
Turner 2x/ week	138	8
Poultry Manure Composts		
No-Turn	163	0
Bucket-Turned	163	5
Turner 1x/ 2 weeks	163	0
Turner 2x/ week	163	0

Table 2.

108 days. Dewar testing is such that we expect values less than 10°C for stabilized composts.

In a later report, we will show data for the Quebec trials comparing chemical and humic effects of intensification. Analyses of Q4/6 ratios, an index of humic maturity, failed to show any statistically significant advantage of turning to no-turning for all compost treatments (Jobin, 1992).

Microbiochemical results

A number of means exist to evaluate compost quality microbiologically and biochemically. We took samples of the dairy and poultry compost piles between days 66 and 75 prior to final stabilization and evaluated enzymatic and microbiological traits (see Table 3)

The results of the microbiochemical examination show some higher hydrolase enzyme activity in unturned or bucket-turned dairy composts but inconclusive difference among young poultry manure composts. We expect hydrolase activity by this test to drop to less than 10 ug/g/min in completed composts and to be as high as 50 in active piles. Dehydrogenase activity which ranges from under 100 to 10,000 TPF units in mature vs. fresh composts gave little consistent trends in these trials with all results being in the moderately stable range.

Bacteria counts of both groups of composts are moderate to high between both aerobic and facultative anaerobic (= aerobes + anaerobes) groups and there is no hydrogen-sulfide activity in any treatment, evidence of a lack of strict anaerobic activity, and overall no evidence that populations were significantly influenced by turning schemes. There were no surviving E. coli or salmonella strains as measured by DNA-probes with a sensitivity of 1 cell/25gr sample. These data overall do not support a conclusion of significant effects derived from the different intensity-turning schedules. Pooling all biochemical data from replicated treatments between compost types gave no statistically significant effects attributable to turning.

Nitrogen and Organic Matter Losses

An important feature of composting is loss of organic matter, clearly evidenced in loss of pile weight and volume. We measured organic matter and nitrogen during the composting and calculated total losses at the end of the process. The data is summarized in Table 4, and all project data including Quebec are graphed in the following Figure 5.

These data show clearly that as intensification of management increases, so do losses, which are significantly correlated between all the trials and treatments. The least losses observed for organic matter and nitrogen were in the Un-turned dairy manure piles which lost 70 and 51%, respectively, and the highest losses observed were in the poultry compost trials where Scarab-turning twice a week gave 88 and 86% loss, respectively, for organic matter and nitrogen. The correlation between organic and nitrogen losses for both the Pennsylvania and Quebec trials are seen in the following figure (Figure 5).

The data clearly show that nitrogen and organic matter losses are closely tied. We did not observe any improvement of losses from increased bedding in the Quebec trials; since any improvement from added carbon was off-set by increased rate of composting and organic loss associated with better porosity.

Economic Factors of Intensification

We examined the costs of intensification of composting for the Pennsylvania trials. This was conducted by tracking inputs, labor and maintenance during operations with the exclusion of equipment capitalization and cost of bulking agents. The following table reproduces the essential features of the study.

In calculating costs, we gave the higher-intensity methods the benefit of the doubt and stopped tabulating costs as soon as stability was indicated by lack of self-heating. We also assigned slightly lower land-area costs to intensive treatment since windrow treatment with straddle-machines required less space. We did not calculate watering/irrigation costs for no-turned piles since they did not have added water. However, irrigation costs were only about 5% of variable costs. Thus, the data clearly indicate that intensive turning brings substantially increased costs which may or may not be off-set by the gain in time or the more homogenous appearance of the final product.

CONCLUSIONS

These findings support the notion that intensification of composting through technology may be unnecessary, certainly if the goal is on-farm nutrient and watershed management and land-application. The needs for pathogen reduction and stabilization are fully met provided the basic requirements for moisture and texture optimization are met. With these results in mind, a low-tech form of composting can be implemented without undue economic or management pressure for farming.

Composting methods that require intensification are a curious result of modern popularity and technological development of composting, as particularly evidenced in popular trade journals. They do not appear to be scientifically supportable based on these studies. Our view of sustainability is analogous to a reduced tillage approach to maximizing soil quality. By carefully managing composting to achieve proper mixes and limited turning, the ideal of a quality product at low economic burden can be achieved.

Within bio-dynamic management, as an example, low-intensive composting has generally been the norm, but has been criticized by modern composters. Based on these studies, it would appear that low-tech composting is more sustainable in view of nutrient and humus-conservation and also costs. Important factors to consider in successfully implementing low-tech minimum turning approaches are correct amount of bedding and moisture control in the compost piles. In view of these results, current approaches to composting must be re-thought in view of modern, sustainable farming practice.

1. The word ***Scarab*** is used generically to identify a large straddle-type window turing machine and does not imply an endorsement or recommendation of any equipment bearing that name.

Biochemical and Microbiological Traits of Differently-Managed Compost Piles

TREATMENT	Hydrolase Activity @ 30C ug FDA/g/min	Dehydro-genase Activity ugTTC/g/hr	Aerobic plate Count	Facultative Anaerobic Count	H_2S Activity pos (+) or minus (-)	E. coli/Salmonella pos or neg
Cow Manure Composts at Day 75						
No-Turn	17	168	10^7	10^6	-	neg
Bucket-Turned	11	222	10^5	10^5	-	neg
Turner 1x/ 2 weeks	0	244	10^5	10^5	-	neg
Turner 2x/ week	2	350	10^5	10^4	-	neg
Poultry Manure Composts at Day 66						
No-Turn	11	188	10^8	10^6	-	neg
Bucket	7	365	10^5	10^5	-	neg
Turner 1x/2 weeks	1	264	10^8	10^7	-	neg
Turner 2x/ week	17	167	10^8	10^6	-	neg

Table 3.

TREATMENT	Organic Matter Loss%	Nitrogen Loss%
Cow Manure Composts @ 120 days		
No-Turn	70	51
Bucket-Turned	78	60
Turner 1x/ 2 weeks	73	53
Turner 2x/ week	80	64
Poultry Manure Composts @ 150 days		
No-Turn	75	72
Bucket-Turned	79	76
Turner 1x/ 2 weeks	79	78
Turner 2x/ week	88	86

Table 4.

Costs Associated with Varying Intensity of Compost Turning	
TREATMENT	Cost $/ wet ton
No-Turning	$3.05
Bucket-Loader Turned	$6.74
Turner 1x/ 2 weeks	$14.34
Turner 2x/ week	$41.23

Table 5.

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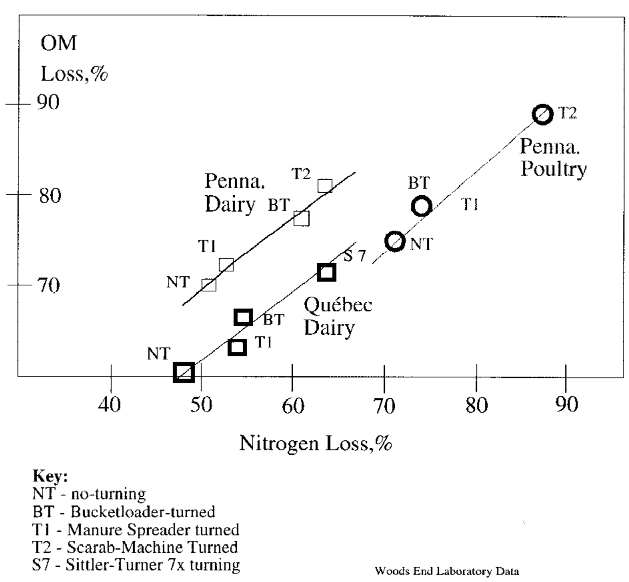
Fig. 5 Effects of Intensification of Composting on Nitrogen and Organic Matter Losses



A full copy of Woods End's USDA study is available for $19.95 by writing to Woods End Institute, PO Box 297, Mt Vernon, Maine 04352.