Analysis of Sampling Conditions, Test Variability and Quality of Composts on Animal Farms in New York State.

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Abstract

Prior to establishing compost quality marketing guidelines, compositional traits and variability of testing across a range of compost samples and types must be established. Little work has been done comparing the variability of farm composts for parameters pertinent to quality guidelines. Nor has sufficient work been done to establish limits for reliability of sampling procedures among farm-compost producers. In a preliminary compost use survey of commercial and home users, respondents indicated strong interest in reported quality of purchased composts. From this survey data the most frequently mentioned issues included product maturity, salt content, presence of weed seed, and physical and chemical contamination. We examine thirty agricultural based composts in a multi-tiered study examining variability of test data with a focus on within-farm variations. Test traits examined included but were not necessarily limited to organic content, C:N, pH, conductivity, NPK content, maturity, phytotoxicity by cress test, fecal coliform content, selected metals, and germinable and dormant weed seeds. In the first phase, 7 farm compost producers were recruited and sampling instructions prepared using a combination of Woods End Laboratory and TMECC sampling and testing guidelines. Two sampling intervals within 2 –4 weeks of each other using two samplers (trained University staff vs. farm-composter) were introduced. Similarly, on selected farms, a re-sampling by the same sampler at a slightly later date from the same pile was undertaken. Finally, where bagging of composts was practiced on the farms, quadruplicate samples were drawn across a single batch of compost bags. To evaluate the resulting data, we employed analysis of variance (ANOVA) which distinguished effects of samplers, dates and farms.

Introduction

Farm compost piles are often of irregular shape and dissimilar dimensions, and therefore prescribed sampling procedures to obtain representative samples may not adequately reflect intrinsic problems of representativeness. Furthermore, composts vary with respect to composition even from farms of fixed animal populations, and vary across time. Seasonal animal management and feeding patterns may affect the composition of manures with regard to moisture and nutrient content. These factors impose uncertainties on farm compost sampling for laboratory testing.

In a New York study Dou et al. (2001) examine variability among animal farms with regard to manure composition. Sample variability within farms, expressed as the coefficient of variation (CV), was mostly 6 to 8% for farms that used agitation in manure storage but much higher (20-30%) on farms where no agitation was applied during the sampling period. Lindley et al (1988) discuss the significant affects handling and storage systems impose on tested manure value. A range of site-specific and temporal aspects will determine the need for more or less samples to obtain reliable data. Peters (2000) discusses sampling technique for manures to reduce variability. In a national survey in Germany, Kreft (1998) draws attention to variability imposed by local conditions. In a major study of contamination for the entire North-Rhine-Westfalen state of Germany, variability of test traits were separated according to commercial fertilizer, sludge and composts. Highly regional effects from industry and farming practice were shown to influence tests traits of composts (NRW, 1999).

In most regards, composting may be similar to the manure systems examined in some of the cited studies, yet other site-specific and technological differences are apparent: such as addition of off-farm ingredients in composts on a seasonal basis and use of compost specific equipment such as turning machines. Seekins et al. (1995) examined paired compost samples from 39 farms and reported significant analytical differences attributable to age of sample and compost management. Discounting the effect of age, test traits still showed some significant dependence on compost technology.

Materials and Methods

Farm Study: We selected seven farms which have similar animal types (dairy) and established 2 sampling events. In the first event two groups of pair samples were each separately taken by the farmer and outside trained extension personnel. Farmers were provided instructions on representative sampling based on compost sampling criteria (Woods End 2001, TMECC, 2001) . The farmer-sampling event was repeated 2-4 weeks later on the same batch of compost material. All samples were taken in duplicate.

Depth Study: After analyzing the data from the 10 farms it was evident that there were unexplained differences in some of the data. There were farms that had differences in some analytes between bulk samples and bagged samples from the same batch. NYS Energy Research and Development Authority (funding source) allowed flexibility for further exploration, therefore a depth study was undertaken. In the second study, we selected three farms with differing physical layout of composts from small to large piles, and examined differences in sampling location within the piles. Large piles are more difficult to sample than small piles, and furthermore large piles may cause differing compost biologies to persist so that layering and other traits develop in a stratified manner. For these farms, three sample locations were established independent of exact pile size and were: Core, 30cm above the pile center bottom; Edge, 30cm from outside; and Middle, half-way between the outer and the core locations.

All samples were sent cooled next day shipping to Woods End Laboratory, coded for location and type. Tests were conducted according to compost procedures taken from the German Compost Methods Manual (Bundesgütegemeinschaft Kompost 1998) and from TMECC (2001, Draft). All data is reported on a dry weight unless otherwise noted.

Results

Farm Study

Table 1 presents and overview of the results form compost samplers within the 7 farm survey. In this survey, we were testing for differences between farm sites, samplers and time of sampling.

Table 1 - Sample Means, Differences and Standard Deviation of Extension vs. Farmer Sampling of 7 Farm Composts

Trait	*Extension Sampler (ES)*	*Farmer Sampler (FS)*	*Diff ES-FS*	*Diff as % of Mean*	*Std Dev Extension*	*Std Dev Farmer*
Moisture	37.4	38.1	0.7	1.9%	8.8	8.7
pH 1:2	7.70	7.58	-0.12	-1.6%	0.6	0.6
Org Content	45.9	45.9	-0.10	-0.2%	17.2	16.9
Conductivity	3.2	3.3	0.07	2.2%	1.8	2.1
C:N Ratio	15.2	14.6	-0.61	-4.1%	4.7	3.3
Germination	96.6	95.6	-0.97	-1.0%	10.0	7.7
Growth Rate	93.0	91.3	-1.73	-1.9%	9.7	9.1
Maturity	6.6	6.4	-0.17	-2.6%	0.8	0.8
CO2 Solvita	6.6	6.5	-0.10	-1.6%	0.8	0.8
NH3 Solvita	4.9	4.8	-0.13	-2.6%	0.3	0.6
F. coliform	425	103	-321	-121.8%	925	187
Weed Seeds	10	16	6	45.2%	24	38
TKN % TS	1.74	1.78	0.04	2.0%	0.8	0.8
P % TS	0.34	0.35	0.01	2.8%	0.2	0.2
K % TS	0.77	0.69	-0.08	-10.3%	0.5	0.5
Cu, ppm	317	285	-33	-10.9%	287	272
Zn, ppm	193	196	4	1.9%	80	88
Fe, ppm	6154	6858	704	10.8%	4547	4419
Mn, ppm	471	509	38	7.8%	238	231

These data show very small numerical differences in test traits of samples averaged for all farms when considering different samplers. The standard deviations of test results within each sample group are much larger than between sample groups, suggesting that statistically the same material is being represented. Only two test traits show differences of more than 11 between the two sampling groups. The CV's for most traits are within expected ranges. There are, however, differences that may be worth noting. Farmer sampled composts gave higher weed seed counts than did extension sampled composts, while the latter gave appreciably higher fecal coliform results. None of the fecal coliform differences were significant according to ANOVA while *farms x sampler interaction effects were* highly significant for weed count ($p \leq 0.009$). The possible source of bias in the sampling was not evaluated. Variance was high in some cases; the standard deviation of extension sample composts for fecal coliform of 925MPN/g is close to the 1000MPN/g EPA 503 limit for PFRP. Therefore, variability factors and handling of numerical values must be for some analytes be addressed more fully.

The mean coefficient of variation (CV) for 19 analytes averaged by farm for all farms ranged from 2 to 115%. Within this same set, the CV for mineral and metal traits ranged from only 3 to 22%. Test data results in dependence on samplers did not differ by more than 10.9% for all 7 farms, excluding the fecal data. Test data in dependence on date of sampling same batches varied somewhat more and up to 106% for zinc content, but generally less than 17%, excepting fecal counts and weeds, which varied by 181 and 171%, respectively. Thus, most source of variability for the test data fall within an expected range of <20%.

Weed seed tests are under development, based on the German method, and may be variable in nature. Furthermore, compost samples must be diluted according to conductivity to prevent salt effects on germination of weeds. Fecal coliform counts are subject to order of magnitude variance, where a single aberrant value may throw off the arithmetic mean of the entire set very considerably. Averaging data sets of this nature is not necessarily the best means to characterize the general properties of the data. An alternative is to employ geometric mean transformation. For example, the geometric mean transformation of our fecal data shows 19 and 13 MPN/g, respectively, for extension and farmer sample groups
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We observed that copper concentrations varied hugely across compost sites. We determined that this depended on the practice of copper sulfate hoof-dips, practiced on some dairy farms. Variance of copper test result between samplers and between time of sampling was acceptably low. However, since copper was high in some composts and a few other metals were higher than expected in a few samples , further testing was added to ensure that other metals were not a problem. Farms, which bagged compost, exhibited appreciable variability in test data between various bags. Bagging operations rely on loading equipment via a hopper by bucket-loads one at a time, and this selective action within a pile may introduce non-homogeneity. Therefore we later examined three farms where depth of sampling is the variable.

Table 2 - Sample Means, Differences and Standard Deviation for Sampling Similar Compost at Differing Time Spans for 7 Farms (n=4)

Trait	*Week 1*	*Week 3*	*Diff Wk1-Wk3*	*Diff as % of Mean*	*Std Dev Week 1*	*Std Dev Week 3*
Moisture	36.7	36.4	-0.4	-1.0%	8.5	9.2
pH 1:2	7.7	7.72	0.02	0.3%	0.7	1.1
Org Content	56.93	51.23	-5.7	-10.5%	12.1	16.9
Conductivity	3	3.8	0.8	22.0%	2.6	2.6
C:N Ratio	12.9	11.9	-1	-8.0%	1.3	1.4
Germination	96.5	94	-2.5	-2.6%	8.1	5.8
Growth Rate	80.5	80	-0.5	-0.6%	15.3	15.1
Maturity	6.3	6.5	0.3	3.9%	1	0.6
CO2 Solvita	6.3	6.5	0.3	3.9%	1	0.6
NH3 Solvita	5	5	0	0.0%	0	0
F. coliform	176	9	-167	-181%	349	9
Weed Seeds	5	61	57	171%	10	111
TKN % TS	2.38	2.29	-0.09	-3.8%	0.5	0.6
P % TS	0.43	0.42	-0.01	-1.9%	0.2	0.2
K % TS	0.76	0.8	0.05	5.9%	0.6	0.7
Cu, ppm	525	506	-19	-3.7%	430	394
Zn, ppm	229	745	515	106%	91	977
Fe, ppm	5285	5687	402	7.0%	4377	4981
Mn, ppm	494	584	90	17.0%	221	287

A factor that affects variability of bagged compost traits is depth in pile, since farm operations in our survey tended to load baggers by bucket direct from piles. The variability of test data was significantly dependent on both depth of sampling with a statistically significant interaction of farm *x* depth. Samples drawn from pile cores exhibited higher pH's, lower nitrate, higher nitrite and higher salt contents than mid or edge samples. VOA, moisture, weed count and fecal counts varied across sample locations in dependence on farm. It is apparent in this data set that without controlling depth of sampling or accounting for stratification of piles obscured in the samples, basic traits like moisture, TKN, salts, density, weed count, and metals could not be established at CV's much under 20%. Table 3 shows the variance (standard deviation as percent of means) for each farm site where the same batch is sampled in duplicate within a 2-month period.

Table 3 - Coefficient of Variance (%) for Test Data by Farm for 10 Sites

Trait	*F-A*	*F-B*	*F-F*	*F-Fb*	*F-G*	*F-Gb*	*F-H*	*F-P*	*F-W*	*F-Wi*	*MEAN*
# Samples	6	4	6	4	4	4	4	4	5	6	-
Moisture	25	6	6	10	3	6	19	2	4	11	8
pH 1:2	2	2	2	2	1	0	3	2	4	3	2
Org Content	4	11	2	14	5	8	8	0	9	13	8
Conductivity	41	30	6	17	36	22	12	10	47	17	22
C:N Ratio	10	15	5	4	11	17	17	8	6	17	11
Germination	20	7	2	1	5	3	19	3	6	3	6
Growth Rate	13	9	15	3	7	48	14	5	11	13	14
Maturity	14	0	9	9	0	9	10	0	0	7	5
CO2 Solvita	14	0	13	9	0	9	10	0	0	7	5
NH3 Solvita	0	0	19	0	11	0	0	0	0	0	3
F. coliform	205	40	159	130	122	158	69	122	203	35	115
Weed Seeds	110	82	-	-	55	45	-	-	224	-	103
TKN % TS	10	9	5	14	11	11	22	8	3	17	11
P % TS	5	5	6	11	6	19	20	7	6	10	10
K % TS	41	15	11	16	19	15	10	4	18	9	13
Cu, ppm	8	9	6	29	20	11	72	7	4	26	21
Zn, ppm	7	2	11	4	3	3	20	3	4	150	22
Fe, ppm	48	14	6	15	15	5	16	8	9	5	10
Mn, ppm	33	16	5	2	7	7	15	4	9	12	9

These data show that the principle variability is clustered in the area of results for fecal coliform and weed seeds with scattered high variability within farms for conductivity and metals. With the exception of these traits, all others appear to fall close to acceptable ranges.

In an attempt to understand better the sources within farm of variability, we examine compost piles individually by farm for varying scenarios of sampling within the pile. A replicated trial of 3 types of samplings (edge, middle and core) was undertaken and the results are shown in Table 4.

Several traits were significantly affected by location within the pile. In the data set, 9 out of 20 variables examined showed statistically significant dependence on the depth of sampling. The variability observed in across-farm sampling for metals, weed and fecal counts was not borne out in the depth study. Here, piles were significantly drier on the surface than mid and core. pH was significantly higher in the core. Nitrite-N, a denitrification by-product, was found in the core, but VOA did not differ appreciably with depth. Of most interest is the higher conductivity and potassium content in the core, indicative of leaching. Many of these differences are expected. For some, such as potassium, a farmer labeling a product for nutrients should be concerned about position in pile of samples In other cases, and overall, the magnitude of the differences in most cases is small.

Table 4 - Compost Test Traits in Dependence of Sampling Location within the Pile (3 Composters)

Trait	*Edge*	*Mid*	*Core*	*Signif.*[1]
Moisture	52.03	67.1	67.27	*** Δ
pH	7.32	8	8.37	** Δ
Org. Matt %	44.3	47.8	46.45	Ns Δ
TKN % TS	1.86	1.53	1.63	*
C:N Ratio	13.4	17.67	16.5	**
Nitrate-N, ppm	190	390	118	Ns
Nitrite-N, ppm	1	2	11	*
VOA, ppm	323	655	602	Ns
Density g/cc	0.77	0.84	0.93	Ns Δ
Conductivity	1.93	4.13	5.23	** Δ
Germination	96	99	102	Ns
Plant Weight	99	82	78	* Δ
Solvita CO2	6	6	7	Ns
Solvita NH3	5	5	4	Ns Δ
Weed Count	4	1	1	*
Fecal coliform	131	28	1	Ns
Cu, ppm	350	264	215	Ns Δ
Mn, ppm	392	363	373	Ns
Fe, ppm	6614	5899	5412	Ns
Zn, ppm	252	538	591	* Δ
Phos %	0.37	0.3	0.29	** Δ
Potash %	0.54	0.89	1.04	**

[1] Significance effects based on ANAOVA for depth effects: asterisks indicate probability where * is $p \leq 0.05$; ** is $p \leq 0.01$ and *** $p \leq 0.001$; Δ denotes significant interaction effect

Table 5 summarizes the results of these studies in terms of factors and their variance.

Table 5 - Relationship of Test Trait Variability to Compost Samples

Analytical Trait affected mostly by FARM	*Analytical trait affected mostly by depth*	*Analytical trait with interaction effects of farm x depth*	*Analytical trait with no apparent relationship*
• ***Organic matter*** • ***Total nitrogen*** • ***C:N ratio*** • ***VOA*** • ***Solvita CO2*** • ***Copper*** • ***Iron***	• ***Moisture content*** • ***pH*** • ***Weed content*** • ***Potassium*** • ***Phosphorus***	• ***Total-nitrogen*** • ***Nitrate*** • ***Salt content*** • ***Cress test*** • ***Ammonia*** • ***Zinc*** • ***Density***	• ***Fecal coliform*** • ***Manganese*** • ***Cress germination*** • ***Manganese***

The data from this study is reassuring in terms of controlling sample test variability among samplers and dates. It suggests that local factors pertaining to management and site conditions may be the primary force in non-uniformity in analytical data. It further suggests that test procedures with large reporting margins such as fecal counts must be handled with consideration of outlying data. As this study is expanded to the next 30 farms, results from the additional analyses are being considered to compile a list of analytes.

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