Modification of Low Quality Dairy Manure Compost with Organic Amendments

Cecilia Gerngross, Randy Bow, Ron Alexander, Mark McFarland and James Supak

Summary

Marketing compost to governmental entities for use on public landscapes, sports fields, playground facilities and road construction provides an option for exporting dairy manure out of the impaired North Bosque River watershed. Composts produced with dairy manure from that area tend to contain high levels of inorganic components (50 to 75%, mainly quartz sand and limestone fragments) and often fail to meet the pH and organic matter standards set by TX DOT and other users. Addition of high carbon amendments to finished composts is being employed as a means to adjust these parameters to meet the TxDOT standards. Four “low quality” compost products were amended with three high carbon by-products (peanut hulls, sawdust and wood chips) by physically mixing the amendments (10% and 30% v/v basis) with the composts. Significant differences *between* the four compost sources were noted for several parameters including organic matter, total N, C:N ratios and pH. Sampling dates (0 DAI and 30 DAI) also resulted in significant differences in organic matter; pH; total P, Ca, and Na; and the bioassay for cucumber seedling vigor, indicating variability *within* the compost products. Adding 10% and 30% high carbon amendments resulted in significantly higher organic matter levels when analyzed *between* compost sources but only the higher (30%) rates significantly increased organic matter contents *across* sources. With the exception of the 30% rate of peanut hulls which produced a significant decrease in pH and a significant increase in total N between compost sources, the organic amendments had no consistent effects on pH, N, P, Ca, Na, soluble salts or cucumber seedling vigor between or across compost sources. Results suggest that the physical mixing of high carbon amendments with low quality dairy manure compost can be used to increase organic matter content and alter C:N ratios but will have limited effects on pH, soluble salts, nutrients or cucumber seedling vigor.

TMECC have been adopted as the industry standards for compost testing but due to strict QA/QC requirements, analytical costs tend to be relatively high. Service laboratories that do not use TMECC or are not STA certified often offer “analytical packages” for lower costs. A comparison of compost test results provided by Soil Control Laboratory (an STA certified laboratory) and the Texas Cooperative Extension Soil, Water Forage Testing Laboratory (a service laboratory) showed that values for selected nutrients (total N, P, Ca, and Na), pH and soluble salts varied significantly between the two laboratories but there were no differences in organic matter levels. Numerically, the mean values obtained by SWFTL were higher for N (7.6%), P (14.8%), Na (59.3%, due in large part to a subsequently identified contamination problem), pH (1%), and soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%). Composters and retailers are required to use TMECC results in marketing their products but service laboratories can be effectively used to provide preliminary assessments of manure and compost quality for use as management decision aids at a fraction of the cost.

Introduction

Composting is an effective means of increasing the utility and value of dairy manure by reducing its weight and volume; minimizing odor, pathogens and weed seeds and transforming the manure into a biologically stable product. This process enables the final product to easily be exported for sale and use to commercial markets far removed from the dairy and composting operations. Compost can be used in agricultural and horticultural applications as a source of plant nutrients and to improve physical properties of soils. It is also used in roadbed and other construction activities alone or in mixtures with other materials for erosion control and modification of disturbed sites to promote establishment of permanent vegetation.

Approximately 75 dairies with an estimated 38,000 cows operate in the Bosque River watershed (Stephenville Special Project Office, TCEQ Region 4). Studies by the Texas Institute for Applied Environmental Research (TIAER) demonstrated that excessive applications of manure to land areas in the immediate proximity of the dairies has contributed to water quality problems in the basin (McFarland and Hauck 1998 and 1999). As early as 1998, interest and support developed for the production of composted dairy manure as a means for encouraging transport of dairy animal wastes out of the watershed. Monetary incentives were provided to encourage manure transport to composting facilities which fostered the establishment of several composting operations in the watershed; Other incentives were initiated to expand government and public markets for composted dairy manure from this area (TCEQ and TSSWCB 2002).

Although numerous public and private entities have taken advantage of the incentive programs, the Texas Department of Transportation (TX DOT) has become, by far, the largest user of dairy manure compost for two primary reasons. First, TX DOT requires large volumes of compost and amended compost products for use in road and highway construction and maintenance. Much of the manure from this watershed contains high levels of levels of sand and frequently fragments of limestone rock. These inorganic contaminants often result in compost products that are unacceptable for top dress applications (i.e. turfgrasses in lawns and sports facilities) but are well suited for use in erosion control along roads and highways. Secondly, TX DOT qualified for incentive payments, which made the use of dairy manure compost a viable and economic alternative for TX DOT.

The dairy compost produced in the Bosque River watershed can also be used to produce compost manufactured topsoil (CMT) and various erosion control compost (ECC) products that comply with TX DOT specification but the general use compost (GUC) typically fails to meet the organic matter (25 to 65%) and pH (5.5 to 8.5) base standards set by TX DOT in 2003. Therefore to capture more of the DOT market, dairy compost producers lobbied for a variance in the specification. In 2004, TXDOT temporarily modified its standard by reducing the organic matter requirement to a minimum of 10% and pH to a maximum of 9.5 for compost generated from livestock and dairy manure. This variance opened the DOT market once again for the compost producers although GUC products from this area frequently fail to meet even the modified standards.

Unfortunately, the variance allowed by the TX DOT was only temporary and more permanent solutions to the low organic matter and high pH material would need to be determined. Proposed solutions include 1) utilization of various techniques to separate organic fractions from the sand and rock contained in the manure, 2) use of organic bedding materials e.g. cotton burs, in lieu of sand, 3) mixing high carbon containing materials e.g. wood chips, with manure prior to composting (Michel, et al, 2005), and 4) mixing high carbon materials with the finished, low quality compost prior to its final screening. The latter is regarded as a potential method for improving the quality of existing compost to meet minimal TX DOT specifications for GUC. A large volume of stockpiled compost currently exists at several of the facilities. While this stockpiled material varies in age, production techniques and stability, it does have one common bond – it is low in organic matter and high in pH. To support the export of the older stockpiled material, compost producers needed to improve its quality.

Sources of various organic by-products in Central Texas were identified by Ron Alexander and Associates in 2004 and include yard waste, tree trimmings, wood chips, sawdust and agricultural by-products (Organic Matter Improvement Survey Report). Composters had previously adopted a mix ratio (v/v basis) of 20 to 25% of a high carbon material with low quality compost to improve organic matter content and reduce pH, but information was lacking on the effectiveness of such treatments in adequately modifying these parameters in existing dairy manure compost to consistently meet TX DOT standards.

The primary objective of this trial was to evaluate the effectiveness of blending available carbon rich by-products with low quality dairy manure composts in modifying organic matter levels, pH and other parameters including particle size, soluble salts, respirometry, cucumber bioassays (germination and vigor) and nutrients. A secondary objective was to compare laboratory methodologies used to analyze composted dairy manures from the North Bosque watershed.

Methods and Materials

Compost Materials

Much of the compost that failed to meet TX DOT specifications has been stored in windrows or large stockpiles at compost yards in the Bosque River watershed for a year or longer. Approximately 2-cubic yards (cy) of dairy manure compost over 1-year old were obtained from stockpiles at two separate compost facilities and designated Composter A and Composter B. Additionally, 2 to 3 cy of compost that were over 3-years old were obtained from from two other facilities designated as Composter C and Composter D, respectively. All compost materials were screened prior to being loaded and transported to the Texas A&M Research and Extension Center at Stephenville, TX. Once at the Station, the materials were covered and kept separated with plastic sheets and stored outdoors until use. Samples of all compost materials were collected on 4/8/2005 and submitted to the Soil Control Lab, 42 Hangar Way, Watsonville, CA and the Soil, Water and Forage Testing Laboratory, Texas Cooperative Extension, College Station, TX for analysis.

Organic Amendments

Wood chips, sawdust and agricultural crop residues (including peanut hulls), were identified as organic by-products that were available in Central Texas in sufficient volume for commercial use in blending with dairy manures and composted materials. For this study, sawdust, consisting of finely ground poplar, ash, oak and pine wood, was obtained from a local cabinet shop and stored until use in 30-gal plastic containers. Finely ground peanut hulls were obtained from a peanut processing facility at Gorman, TX and stored in large plastic woven bags until use. Shredded wood chips (consisting of trimmings from hackberry, mesquite, cedar, oak and other tree species) were obtained from a local tree service. The wood chips were mechanically shredded to further reduce their size (to approximately 2-3 inch lengths) using a small chipper/shredder and were stored outdoors until use. Samples of the organic amendments were collected on 4/8/2005 and submitted to the Soil Control Lab for analysis.

Blending of Composts and Organic By-Products

Blending ratios of 10% and 30% organic by-products to compost (v/v basis) were used in this study. Theoretically, because of the high content of inorganic material (50-75%), much higher levels of organic amendments might be required to appreciably change compost composition. Inputs from the composters and others, however, indicated that addition of organic by-products in excess of 20 to 25% may not be economically practical.

Treatments used in the trial included 4 sources of dairy manure compost amended with 3-organic by-products (woodchips, sawdust and peanut hulls) that were applied at 2-rates (10% and 30% v/v basis). Each of the 72 treatments was replicated 3-times. Since the approved protocol for this study did not include non-amended compost treatments, a companion test was initiated that included only the 4-compost materials replicated 3-times. This essentially set up a split plot design with compost sources as the main plots and the amended compost treatments as the sub-plots.

Individual treatments were prepared as follows: The average weight of 0.67 ft^3 of each compost product and organic by-product was determined by filling and weighing the respective material in 5-gal buckets. Buckets were filled with the appropriate material, tamped once on a concrete floor, leveled with a straight edge and weighed. Additionally, the weight of each organic amendment needed to prepare the 10% and 30% blends was calculated.

The 5.0 gal (0.67 ft^3) container of compost and the appropriate, pre-weighed, amount of organic amendment were dumped into a small cement mixer and thoroughly mixed (for 3-4 minutes) mechanically and by hand to ensure homogeneity. Two samples were obtained for laboratory analysis using the TMECC sampling procedure (collecting 5-subsamples with a trowel to form a composite sample that was subdivided and the appropriate amounts transferred to labeled quart size plastic “zip-lock” bags). The remaining compost-organic amendment blend was transferred from the mixer to the original 5-gal container, leveled with a straight edge, weighed and randomly positioned in a large, open shop area. The plastic bags containing the samples were packed into 5-gal buckets, cooled to 4ºC in a cold storage unit and shipped overnight to the appropriate laboratories

Prior to initiation of the trials, a few treatments were prepared to test the procedures described above and to monitor the samples for changes (settlement, temperature changes, moisture accumulation). Further, temperatures of treatments were randomly monitored for approximately 10-days following initiation of the trials and confirmed that minimal biological activity (indicative of further or renewed composting) resulted from the blending of the composts with the organic amendments.

Treatments were re-sampled approximately 30 and 60-days after initiation (DAI) of the study. Each 5-gal container was again dumped in the cement mixer, stirred for 2-3 minutes, sampled and processed as described above with the exception that the containers were not re-weighed.

Chemical and Physical Properties

Changes in chemical properties of the composts and amended composts were monitored by submitting samples to Soil Control Lab (SCL), 42 Hangar Way, Watsonville, CA 95076 for analysis according to standard protocols specified by the US Composting Council's Test Methods for Examination of Composting and Compost (TMECC, 2002), Table 1. Determinations included moisture content, C:N ratios; organic matter content; soluble salts; pH; total N, P, Ca, and Na; particle size; respiration and cucumber bioassays (germination and vigor) for the 0 and 30 day sampling periods. The total P, Ca and Na determinations and the respiration and cucumber bioassays were excluded for the samples collected 60 DAI.

Duplicate samples from the 0 and 30 day sampling periods were also submitted to the Soil, Water and Forage Testing Laboratory (SWFTL), Texas A&M University, College Station, TX. The SWFTL is primarily a service laboratory which is not STA certified and therefore, does not solely utilize TMECC procedures in its compost testing protocols. For example, the SWFTL employs a modified dry combustion procedure (LOI) to estimate total organic carbon when testing materials that contain carbonates (Pitt, et al, 2003). Determinations made by the SWFTL include total organic carbon (LOI), soluble salts, pH, N, P, K, Ca, Mg, Na, Zn, Fe, Cu, and Mn, Table 1.

Wet and air dry bulk densities were estimated from the volumes and weights of the composts and amended composts determined during preparation of the individual treatments. Moisture determinations for each sample were made by the testing laboratories.

Data Analysis

Resulting data were analyzed to ascertain treatment differences across and between compost sources using standard SAS procedures for AOV and means separations. Since the experimental design used was not a factorial due to the inclusion of control treatments, data were analyzed with both a split-plot application of a repeated measure design and a general linear model (GLM) application of a repeated measure design. The Dunnett and Tukey tests were used to test for differences of least square means at the 95% confidence level. The same models were used to compare (across compost sources only) the test results obtained by the SCL and SWFTL.

Statistical analyses were conducted by Dr. Keith Schumann, formerly a graduate student in the Department of Agricultural Economics, Texas A&M University and currently with Welch Consulting, Bryan, TX.

Table 1. Methodology utilized by Soil Control Laboratory (SCL) and by the Soil, Water and Forage Testing Laboratory (SWFTL).

Parameter	SCL Method (TMECC Method)	SWFTL SOP
Chemical Properties		
Electrical Conductivity	04.10-A	0072R0
PH	04.11-A	0071R0
Organic Properties		
Organic Matter	05.07-A	0060R0
Fecal Coliform	07.01-B	--
Metals		
Magnesium	04.12-B/04.14-A	0074R0
Sodium	04.12-B/04.14-A	0074R0
Manganese	04.12-B/04.14-A	0074R0
Copper	04.12-B/04.14-A	0074R0
Calcium	04.12-B/04.14-A	0074R0
Zinc	04.12-B/04.14-A	0074R0
Iron	04.12-B/04.14-A	0074R0
Arsenic	04.12-B/04.14-A	--
Chromium	04.12-B/04.14-A	--
Cadmium	04.12-B/04.14-A	--
Lead	04.12-B/04.14-A	--
Mercury	04.12-B/04.14-A	--
Molybdenum	04.12-B/04.14-A	--
Nickel	04.12-B/04.14-A	--
Selenium	04.12-B/04.14-A	--
Nutrients		
Total Nitrogen	04.02-D	0073R0 / 0075R0
Total Phosphorus	04.12-B/04.14-A	0074R0
Total Potassium	04.12-B/04.14-A	0074R0
Physical Properties		
Particle Size	02.02-B	--
Maturity	05.05-A	--
Stability	05.08-B	--
Moisture	03.09-A	--

Results and Discussion

The chemical, physical and biological properties of dairy manure composts and organic amendments used in these trails as determined by SCL using STA-TMECC procedures are summarized in Table 2 and the chemical properties, as determined by SWFTL are presented in Table 3. The mean chemical, physical and biological properties of the compost and amended compost treatments used in the study as determined by the SCL are presented in Table 4 and those determined by the SWFTL are shown in Table 5. Only the STA-TMECC results provided by the SCL were statistically tested to ascertain treatment differences and those results are summarized in Tables 6 and 7.

Variations within and among compost sources and lots are common and proper sampling is essential to ensure representative samples are obtained for laboratory testing. TMECC procedures were used in sampling each compost product but even then, variability within each source remained a factor as evidenced by significant sampling day effects on several test parameters (i.e. organic matter, total P), Tables 6 and 7.

Compost Sources

Dairy manures constitute the basic feedstocks for commercial composts produced in the Upper Bosque watershed. These feedstocks vary in composition/qualities due to management practices and adulterations at the dairies and composting facilities. Manure composition and quality is influenced by the feed rations, bedding materials, other additives (i.e. push-down feed), waste management (solid-water separation, storage) systems and other practices used by the multiple dairies from which feedstocks are obtained. Thus, the resulting feedstock can vary from primarily organic solids that were separated from potential contaminants to those that contain manure with varying amounts of extraneous matter such as bedding materials, sand, rock fragments, etc. Collection (frequency, loading methods) and transport of manures to the compost facilities and the composting, storage and handling processes used by the individual compost producers also affect the quality of the final product. High levels of inorganic materials (primarily sand and limestone rock) reduce organic matter levels. Storage of raw manure and finished compost, windrow construction, frequency and uniformity of mixing, temperature and moisture control are all factors in producing products that will meet customer specifications.

Variability of Compost Sources

Significant differences in pH, total N and C:N ratios occurred between the four compost sources used in this study, Tables 6 and 7. Organic matter content of Compost C and Compost D were similar but significantly lower than those of Compost A and Compost B. Compost B contained significantly higher levels of Ca and Na than the other products, Table 7. All other parameters (except cucumber seedling vigor) did not differ significantly between the four compost sources.

Table 2. Chemical, biological and physical properties of four dairy manure composts and three organic by-products determined by the Soil Control Laboratory. (Note: need to add bulk densities)

Sample ID	C:N ratio	OM content	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size <5/8"	Size <3/8"	Respiration	Cucumber Bioassay	
		% dw	umhos/cm		% dw	-------------mg/kg dw-------------			---------%--------		mg CO2-C/gOM/d	% germ	% vigor
Composter A	14.00	10.47	1495	9.77	0.58	2207.5	31078.5	1924.5	100	100	1.735	100	95
Composter B	15.00	13.67	1665	9.285	0.835	4048.5	119201.5	1725.5	100	98.5	0.695	50	90
Composter C	12.50	7.53	2190	8.185	0.425	1330.5	43823	1117.5	100	98.5	0.71	100	90
Composter D	13.00	8.765	1630	9.13	0.505	2671	61646	760.5	100	100	0.765	80	50
Source A (Sawdust)	643.50	99.68	1180	3.975	0.082	49.5	347	85.5					
Source B (Peanut Hulls)	56.00	95.915	5120	5.62	0.9	414	1967.5	377.5					
Source C (Wood Chips)	143.50	95.46	2270	6.705	0.36	274.5	6029	73					

Table 3. Chemical properties of four dairy manure composts determined by the Soil, Water and Forage Testing Laboratory.

Rep	Sample ID	LOI	Soluble Salts	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
		%	umhos/cm	units	---------------------------------------%---------------------------------------						--------------------ppm--------------------				%
1	Composter A	10.4	1532	9.3	0.4760	0.2032	0.5040	3.01	0.2798	0.2723	83.9	5300	23.08	160.7	25.4
2	Composter A	11.3	1743	9.2	0.5100	0.2005	0.5328	3.24	0.2879	0.2843	84.3	5461	24.59	164.0	24.7
1	Composter B	17.1	2245	8.8	0.8560	0.4531	0.9838	12.24	0.6666	0.3425	211.7	8704	46.14	280.8	27.8
2	Composter B	16.2	1982	8.7	0.8240	0.4417	0.9091	12.16	0.6299	0.3198	202.4	8028	43.76	270.5	27.2
1	Composter C	7.6	1982	8.1	0.4040	0.1302	0.5141	4.62	0.3478	0.2223	59.3	6712	13.57	166.5	23.4
2	Composter C	8.1	1709	8.1	0.4210	0.1378	0.5694	4.67	0.3762	0.2334	62.1	7264	13.62	180.4	24.1
1	Composter D	8.1	1720	8.9	0.4850	0.2858	0.8229	6.51	0.4324	0.2473	86.6	9655	19.64	217.4	23.4
2	Composter D	8.7	1487	8.4	0.4720	0.2838	0.8092	6.55	0.4289	0.2123	85.5	8926	19.21	222.4	23.7

Table 4. Mean chemical, biological and physical properties of the compost and amended compost treatments determined by Soil Control Laboratory 0, 30 and 60 days after initiation (DAI) of the study.

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	Mg CO2-C/gOM/d	% germ	% vigor	%	g/cm^3
Composter A	0	--	0	13.67	10.02	1215	9.3	0.480	1957	35001	1790	100	100	1.64	100	99	22.4	1.095
Composter A	0	A	10	16.67	12.59	1109	9.2	0.480	1951	36156	1822	100	100	2.45	100	95	23.1	0.994
Composter A	0	A	30	22.00	17.10	924	9.1	0.400	1983	35882	2046	100	98	1.66	100	99	22.7	1.030
Composter A	0	B	10	16.00	12.26	1175	9.1	0.470	1780	34999	1583	100	100	1.81	100	95	23.5	0.993
Composter A	0	B	30	19.00	16.03	1274	8.8	0.533	1976	39131	2280	100	100	2.11	96	99	23.9	0.991
Composter A	0	C	10	15.00	12.42	1228	9.1	0.463	1845	36780	1668	100	97	1.02	97	95	24.6	1.016
Composter A	0	C	30	26.67	22.68	1276	9.1	0.450	1697	31034	1828	98	96	1.51	100	100	25.6	0.941
Composter A	30	--	0	11.67	9.48	1158	9.4	0.353	2021	33514	1649	100	99	2.53	100	99	21.4	
Composter A	30	A	10	14.33	12.46	1184	9.4	0.493	1759	41474	1443	100	100	2.27	100	95	21.6	
Composter A	30	A	30	20.00	17.35	918	9.2	0.447	1784	35354	1492	100	100	2.02	100	100	20.7	
Composter A	30	B	10	14.00	11.93	1293	9.3	0.477	1875	30249	1504	100	99	2.06	100	98	21.0	
Composter A	30	B	30	17.33	15.29	1054	9.3	0.507	1858	41305	1489	100	99	2.00	N/A	85	21.6	
Composter A	30	C	10	14.33	11.46	1284	9.2	0.453	1813	31918	1511	89	97	2.11	100	99	21.7	
Composter A	30	C	30	14.33	13.65	1106	9.1	0.550	1719	31156	1212	99	97	2.27	100	87	23.3	
Composter A	60	--	0	11.33	8.51	2034	9.0	0.453				100	100					
Composter A	60	A	10	13.00	10.39	1734	9.0	0.363				100	100					
Composter A	60	A	30	15.67	15.09	1312	8.6	0.417				100	99					
Composter A	60	B	10	12.00	10.93	1884	9.2	0.477				100	99					
Composter A	60	B	30	14.67	14.18	1624	9.3	0.473				100	100					
Composter A	60	C	10	14.00	11.59	1762	9.2	0.470				100	99					
Composter A	60	C	30	19.00	14.99	1660	9.1	0.447				99	97					
Composter B	0	--	0	14.67	14.48	1416	9.1	0.807	4740	125861	1939	100	97	0.28	100	100	25.2	1.112
Composter B	0	A	10	17.00	17.19	1252	9.0	0.803	3656	119661	1773	100	95	0.89	98	97	26.5	0.983
Composter B	0	A	30	20.00	19.36	1129	8.8	0.727	3591	156205	2187	100	99	0.89	100	98	23.6	0.873
Composter B	0	B	10	16.67	15.58	1393	8.9	0.813	3325	134613	1796	100	95	1.75	97	98	23.9	1.003
Composter B	0	B	30	19.00	19.11	1257	8.7	0.703	3326	126916	1662	100	98	2.22	100	99	24.8	0.899
Composter B	0	C	10	17.67	18.06	1459	9.0	0.687	2298	119339	1491	100	95	0.93	100	96	27.7	0.990
Composter B	0	C	30	26.00	27.76	1276	8.9	0.693	3338	111826	2062	100	93	1.32	97	98	28.6	0.956

Table 4 (cont'd). Analysis from Soil Control Laboratory

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	mg CO2-C/gOM/d	g/cm3	% vigor	%	g/cm^3
Composter B	30	--	0	15.33	14.36	1526	8.7	0.703	3261	136078	1318	100	97	1.31	100	100	21.3	
Composter B	30	A	10	9.67	16.83	1182	8.9	0.867	3669	132206	1791	100	95	1.44	100	72	24.5	
Composter B	30	A	30	19.33	19.13	988	8.9	0.677	3231	133234	1382	100	95	1.32	100	100	22.9	
Composter B	30	B	10	15.67	15.12	1271	8.9	0.853	3384	128564	1640	99	94	0.76	100	95	22.2	
Composter B	30	B	30	18.00	23.17	1241	8.9	0.863	3238	137966	1234	100	94	1.08	100	61	22.0	
Composter B	30	C	10	16.33	16.04	1430	8.8	0.790	3346	116542	1465	98	92	1.35	100	77	24.6	
Composter B	30	C	30	18.33	15.69	1308	8.8	0.813	3249	104937	1713	97	88	1.69	100	100	22.6	
Composter B	60	--	0	14.33	14.42	2212	8.8	0.737				100	93					
Composter B	60	A	10	15.67	15.85	1823	8.9	0.727				100	95					
Composter B	60	A	30	16.67	17.47	1544	8.8	0.813				100	94					
Composter B	60	B	10	15.00	15.73	1834	8.6	0.890				100	92					
Composter B	60	B	30	16.33	18.14	1928	8.6	0.920				100	94					
Composter B	60	C	10	14.00	14.87	2033	8.7	0.907				100	90					
Composter B	60	C	30	16.33	19.80	1546	9.1	0.813				99	90					
Composter C	0	--	0	14.00	7.93	1858	8.0	0.400	1346	51196	1528	100	99	0.16	88	99	22.1	1.295
Composter C	0	A	10	14.00	9.89	1541	7.7	0.423	1266	41363	1448	100	99	4.51	94	97	21.5	1.155
Composter C	0	A	30	20.33	13.67	1354	7.6	0.423	1204	45593	1325	100	98	6.78	100	99	19.8	1.001
Composter C	0	B	10	16.00	10.19	1564	7.8	0.470	1359	48659	1464	100	99	1.48	106	99	20.1	1.164
Composter C	0	B	30	17.33	13.22	1514	7.5	0.400	1181	44209	1593	100	98	1.78	112	98	20.8	1.036
Composter C	0	C	10	15.00	9.65	1565	7.7	0.433	1181	48424	1375	98	96	0.58	118	100	21.5	1.169
Composter C	0	C	30	25.67	14.52	1625	7.8	0.430	1150	46629	1283	99	97	1.23	124	100	22.2	1.018
Composter C	30	--	0	17.67	7.90	1716	7.8	0.287	1409	54343	1112	100	99	1.81	88	95	20.0	
Composter C	30	A	10	20.33	9.15	1413	8.2	0.303	1555	58769	1335	100	98	3.84	94	99	19.7	
Composter C	30	A	30	27.33	11.61	917	8.6	0.287	1425	68595	1368	100	100	3.81	100	100	19.2	
Composter C	30	B	10	19.00	9.91	1694	7.9	0.377	1097	49822	1176	100	97	1.19	106	96	20.8	
Composter C	30	B	30	22.00	12.03	1507	8.0	0.267	1145	51457	949	100	97	1.24	112	88	19.5	
Composter C	30	C	10	22.33	8.79	1620	7.8	0.250	1232	70710	1257	98	96	1.76	118	91	20.8	
Composter C	30	C	30	18.67	15.24	1552	8.1	0.457	1187	41192	1027	99	93	2.31	124	94	21.5	

Table 4 (cont'd). Analysis from Soil Control Laboratory

Sample ID	Sample Interval	Added Carbon		C:N ratio	OM	Soluble Salts	pH	Total N	Total P	Total Ca	Total Na	Size		Respiration	Cucumber Bioassay		Moist	Bulk Dens.
	DAT	Source	Level		% dw	umhos/cm (1:5 w/w)	units (1:5 w/w)	%	mg/kg	mg/kg	mg/kg	<5/8"	<3/8"	mg CO2-C/gOM/d	% germ	% vigor	%	g/cm^3
Composter C	60	--	0	11.00	8.12	2460	8.0	0.463				100	97					
Composter C	60	A	10	13.00	7.69	2027	7.9	0.467				100	96					
Composter C	60	A	30	16.33	10.24	1219	8.8	0.463				100	97					
Composter C	60	B	10	13.00	9.01	2243	7.9	0.507				100	97					
Composter C	60	B	30	14.33	12.61	1953	7.8	0.507				100	96					
Composter C	60	C	10	12.00	8.19	2016	7.8	0.473				99	94					
Composter C	60	C	30	14.67	9.04	1687	8.0	0.417				99	93					
Composter D	0	--	0	12.67	8.34	1294	9.0	0.437	2415	56892	1114	70	97	0.47	N/A	94	21.9	1.276
Composter D	0	A	10	16.00	11.05	1319	8.8	0.433	2214	63192	799	99	96	2.47	N/A	97	21.5	1.164
Composter D	0	A	30	21.67	15.97	935	8.7	0.410	1962	66148	746	100	98	1.62	97	94	19.9	1.025
Composter D	0	B	10	14.33	10.63	1239	8.8	0.430	1925	77547	1034	100	97	1.35	97	96	20.6	1.139
Composter D	0	B	30	18.00	13.19	1208	8.7	0.423	2021	60969	831	100	99	1.81	N/A	90	20.4	1.001
Composter D	0	C	10	14.67	9.29	1264	9.0	0.423	1963	61350	877	99	96	1.56	99	100	21.1	1.091
Composter D	0	C	30	15.33	12.71	1202	8.9	0.440	2478	61237	610	99	96	2.36	100	100	21.4	0.981
Composter D	30	--	0	12.67	7.56	1292	9.0	0.503	2744	67840	1116	100	97	1.48	N/A	50	20.9	
Composter D	30	A	10	15.67	9.51	1119	9.0	0.447	2534	68356	869	100	99	1.95	100	70	19.1	
Composter D	30	A	30	21.00	13.56	857	8.9	0.480	2718	83677	1085	100	97	1.38	100	38	18.7	
Composter D	30	B	10	14.00	9.60	1383	9.0	0.480	2759	64946	1001	100	98	0.73	100	63	18.0	
Composter D	30	B	30	16.67	13.09	1161	9.0	0.427	2377	61005	997	100	97	1.83	100	47	17.8	
Composter D	30	C	10	16.67	8.84	1379	8.8	0.400	2745	63789	1060	100	98	1.39	100	53	19.4	
Composter D	30	C	30	20.00	13.15	1338	8.9	0.417	3296	76217	1151	98	92	1.63	N/A	50	17.6	
Composter D	60	--	0	11.67	7.81	1903	8.7	0.437				100	97					
Composter D	60	A	10	13.67	8.76	1312	8.9	0.440				100	95					
Composter D	60	A	30	17.67	10.76	1044	8.4	0.423				96	90					
Composter D	60	B	10	13.67	8.83	1907	8.7	0.433				99	92					
Composter D	60	B	30	16.67	12.22	1778	8.6	0.467				99	98					
Composter D	60	C	10	13.00	9.14	1669	8.7	0.410				100	96					
Composter D	60	C	30	14.00	11.26	1884	8.7	0.440				100	95					

Table 5. Mean chemical properties of compost and amended compost treatments determined by the Soil, Water and Forage Testing Laboratory 0 and 30 days after initiation (DAI) of the study.

Sample ID	Sampling Interval	Added Carbon		LOI	Soluble Salts	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
	DAT	Source	Level	%	umhos/cm	units	%	%	%	%	%	%	ppm	ppm	ppm	ppm	%
Composter A	0	--	0	10.1	1466	9.53	0.489	0.214	0.577	2.955	0.291	0.304	77.8	6282	1.30	176	22.6
Composter A	0	A	10	11.7	1347	9.47	0.560	0.192	0.523	2.797	0.275	0.318	70.3	5996	1.31	166	23.0
Composter A	0	A	30	15.6	1297	9.37	0.455	0.182	0.493	2.583	0.261	0.294	66.1	5343	1.32	156	42.6
Composter A	0	B	10	11.4	1486	9.53	0.495	0.195	0.534	2.788	0.288	0.321	70.4	5318	1.33	166	23.1
Composter A	0	B	30	14.4	1449	9.57	0.505	0.194	0.551	2.793	0.295	0.327	70.9	5125	1.33	169	23.1
Composter A	0	C	10	10.0	1365	9.63	0.479	0.193	0.513	2.829	0.280	0.297	39.4	5463	14.21	162	23.6
Composter A	0	C	30	10.5	1361	9.63	0.493	0.198	0.535	2.906	0.289	0.315	39.2	5652	13.22	168	24.8
Composter A	30	--	0	10.1	1441	9.53	0.493	0.203	0.530	2.952	0.291	0.337	84.5	5854	21.71	174	22.7
Composter A	30	A	10	12.4	1165	9.37	0.508	0.203	0.538	3.016	0.293	0.330	83.6	5909	21.89	173	21.5
Composter A	30	A	30	16.5	1449	9.07	0.478	0.188	0.492	2.736	0.271	0.328	77.5	5428	20.65	161	20.8
Composter A	30	B	10	11.7	1373	9.43	0.515	0.202	0.535	2.929	0.294	0.347	83.3	6092	21.50	173	22.1
Composter A	30	B	30	13.4	1404	9.17	0.524	0.198	0.537	2.854	0.297	0.329	81.1	5507	21.26	166	21.6
Composter A	30	C	10	10.2	1345	9.43	0.504	0.201	0.523	2.962	0.292	0.349	83.2	5744	22.07	172	22.8
Composter A	30	C	30	10.6	1313	9.40	0.516	0.203	0.519	2.991	0.292	0.338	83.0	5707	22.47	170	23.8
Composter B	0	--	0	16.4	1989	9.03	0.854	0.451	1.062	13.556	0.690	0.415	161.3	9488	36.20	290	24.2
Composter B	0	A	10	18.6	1814	9.10	0.815	0.430	1.018	12.411	0.659	0.404	152.7	8978	34.06	280	25.9
Composter B	0	A	30	23.6	1608	9.10	0.753	0.402	0.922	11.486	0.608	0.347	143.0	8208	32.50	263	24.6
Composter B	0	B	10	17.5	1248	9.17	0.784	0.419	0.954	11.925	0.631	0.325	149.0	8574	29.87	269	23.9
Composter B	0	B	30	21.5	1826	9.03	0.821	0.414	0.996	12.021	0.643	0.320	146.6	8148	29.35	262	24.4
Composter B	0	C	10	16.4	1894	9.13	0.834	0.433	1.006	13.012	0.661	0.314	159.3	8850	30.94	281	26.4
Composter B	0	C	30	16.9	1766	9.17	0.816	0.437	1.019	13.188	0.671	0.319	158.0	9010	31.81	281	26.4
Composter B	30	--	0	16.7	2237	8.77	0.851	0.459	1.022	13.156	0.695	0.413	204.3	9444	45.59	299	26.0
Composter B	30	A	10	18.2	1532	9.07	0.820	0.438	0.974	12.759	0.661	0.387	193.9	9436	44.90	287	23.8
Composter B	30	A	30	22.2	1683	8.80	0.766	0.423	0.939	12.641	0.646	0.372	194.6	8913	42.50	277	23.3
Composter B	30	B	10	18.5	1596	8.93	0.835	0.454	0.973	12.985	0.680	0.374	203.9	9095	43.77	294	22.8
Composter B	30	B	30	20.9	1536	8.87	0.841	0.440	1.007	12.933	0.683	0.391	196.7	8952	42.56	295	23.5
Composter B	30	C	10	16.2	1837	8.80	0.815	0.455	0.994	13.222	0.688	0.386	206.0	9428	44.11	297	23.9
Composter B	30	C	30	17.4	1499	9.07	0.812	0.450	1.001	13.428	0.687	0.376	203.5	9619	43.58	298	24.2

Table 5 (cont'd). Analysis from Soil, Water and Forage Testing Laboratory

Sample ID	Sampling Interval	Added Carbon		LOI	Soluble Salts	pH	N	P	K	Ca	Mg	Na	Zn	Fe	Cu	Mn	Mois
	DAT	Source	Level	%	umhos/cm	units	%	%	%	%	%	%	ppm	ppm	ppm	ppm	%
Composter C	0	--	0	8.0	1919	8.23	0.433	0.138	0.557	4.556	0.367	0.240	16.5	7055	3.24	176	21.9
Composter C	0	A	10	9.5	1858	8.10	0.372	0.130	0.547	4.299	0.370	0.236	14.0	6864	2.76	171	21.8
Composter C	0	A	30	13.4	1611	8.33	0.389	0.130	0.553	4.189	0.357	0.285	13.5	6706	2.96	173	19.8
Composter C	0	B	10	9.4	1556	8.97	0.391	0.136	0.595	4.595	0.376	0.269	15.1	7194	3.02	181	21.3
Composter C	0	B	30	11.6	1412	8.87	0.380	0.128	0.551	4.058	0.350	0.254	13.4	6615	2.76	163	23.0
Composter C	0	C	10	7.9	1802	8.27	0.406	0.137	0.594	4.768	0.403	0.263	15.6	7331	2.74	188	21.6
Composter C	0	C	30	8.5	1531	8.63	0.396	0.141	0.581	4.795	0.388	0.260	16.6	7351	2.76	189	21.2
Composter C	30	--	0	8.0	1969	8.20	0.338	0.144	0.552	4.558	0.380	0.303	64.4	7932	14.91	194	21.4
Composter C	30	A	10	8.1	1381	8.40	0.386	0.140	0.561	4.594	0.385	0.294	63.0	7839	14.93	188	20.3
Composter C	30	A	30	11.4	902	8.60	0.408	0.143	0.566	4.607	0.383	0.292	62.6	7898	14.56	191	19.8
Composter C	30	B	10	9.1	2085	7.87	0.439	0.148	0.588	4.757	0.401	0.290	65.2	7867	14.14	193	19.6
Composter C	30	B	30	11.3	1357	8.13	0.436	0.138	0.569	4.502	0.385	0.288	62.3	7570	13.61	183	20.2
Composter C	30	C	10	8.0	1881	7.97	0.408	0.139	0.565	4.504	0.392	0.267	62.9	7973	12.90	192	20.0
Composter C	30	C	30	7.1	1195	8.27	0.415	0.145	0.570	4.925	0.397	0.289	64.9	7844	13.49	192	20.1
Composter D	0	--	0	8.6	1541	9.10	0.449	0.285	0.850	6.620	0.436	0.256	39.2	8914	6.55	218	21.4
Composter D	0	A	10	11.2	1442	9.10	0.471	0.277	0.823	6.207	0.425	0.273	36.8	8627	6.66	214	21.1
Composter D	0	A	30	15.1	1240	8.93	0.480	0.261	0.765	5.807	0.403	0.233	33.0	8447	4.89	203	20.4
Composter D	0	B	10	10.9	1451	9.20	0.363	0.275	0.814	6.107	0.428	0.248	36.2	8528	5.91	212	16.5
Composter D	0	B	30	13.5	1472	8.93	0.538	0.271	0.817	5.897	0.422	0.259	34.1	8419	5.37	207	20.4
Composter D	0	C	10	9.0	1331	9.13	0.515	0.279	0.828	6.503	0.431	0.272	37.6	8868	7.60	222	23.9
Composter D	0	C	30	9.4	1401	9.20	0.519	0.279	0.825	6.332	0.426	0.243	37.6	8681	5.44	211	21.0
Composter D	30	--	0	8.2	1347	8.90	0.486	0.296	0.838	6.489	0.457	0.297	87.5	9825	18.02	228	19.8
Composter D	30	A	10	10.6	1382	8.83	0.478	0.293	0.815	6.400	0.451	0.292	86.6	9646	18.10	225	19.8
Composter D	30	A	30	13.8	813	8.93	0.464	0.281	0.774	6.339	0.435	0.271	82.7	9445	16.99	221	19.1
Composter D	30	B	10	9.7	1566	8.77	0.393	0.295	0.839	6.316	0.455	0.272	87.0	9619	17.20	221	19.5
Composter D	30	B	30	12.8	1056	8.77	0.508	0.287	0.832	6.285	0.458	0.258	84.3	9548	16.87	222	18.7
Composter D	30	C	10	8.9	1019	8.47	0.482	0.302	0.834	6.772	0.464	0.292	89.0	10049	17.95	233	19.6
Composter D	30	C	30	9.3	1271	8.73	0.481	0.291	0.804	6.306	0.444	0.271	83.4	9742	16.54	226	19.3

Table 6. Influence of Compost sources, incorporation of high carbon byproducts (v/v basis) and sampling dates (0, 30, and 60 DAI) on organic matter, total N, pH, and soluble salts. Differences were determined by Dunnett's means separation test between and across compost sources.

Comparisons	Organic Matter (%)	Total N (%)	pH	Soluble Salts (umhos/cm)
Between Compost Sources				
Compost Sources				
Composter A vs. Composter C	*	*	*	n.s.
Composter B vs. Composter C	*	*	*	n.s.
Composter D vs. Composter C	n.s.	*	*	n.s.
Carbon Sources Volumes				
Source A 10 vs. Control	*	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.
Source B 10 vs. Control	*	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	*	*	n.s.
Source C 10 vs. Control	*	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.
Sampling Dates				
2 vs. 1	*	n.s.	*	n.s.
3 vs. 1	*	n.s.	n.s.	*
Across Compost Sources				
Carbon Sources Volumes				
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.
Sampling Dates				
2 vs. 1	*	n.s.	*	n.s.
3 vs. 1	*	n.s.	n.s.	*

n.s- not significantly different at 95% confidence level
*- significantly different at 95% confidence level

Table 7. Influence of compost sources, incorporation of high carbon byproducts (v/v basis) and sampling dates (0 and 30 DAI) on C:N Ratios, nutrients (N,P, K, Ca, Na), respiration, and cucumber seedling vigor. Differences determined by Dunnett's mean separation tests between and across compost sources.

Comparisons	C:N Ratio	Total P (%)	Total Ca (%)	Total Na (%)	Cucumber Bioassay (%/vigor)
Between Compost Sources					
Compost Sources					
Composter A vs. Composter C	*	n.s.	n.s.	n.s.	n.s.
Composter B vs. Composter C	*	n.s.	*	*	n.s.
Composter D vs. Composter C	*	n.s.	n.s.	n.s.	*
Carbon Sources Volumes					
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Sampling Dates					
2 vs. 1	n.s.	*	*	*	*
Across Compost Sources					
Carbon Sources Volumes					
Source A 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source A 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source B 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source B 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Source C 10 vs. Control	n.s.	n.s.	n.s.	n.s.	n.s.
Source C 30 vs. Control	*	n.s.	n.s.	n.s.	n.s.
Sampling Dates					
2 vs. 1	n.s.	*	*	*	*

n.s- not significantly different at 95% confidence level
*- significantly different at 95% confidence level

Organic Matter and pH

Dairy manure composts from the Bosque River Watershed frequently fail to meet the TXDOT specifications for organic matter content and pH. Consequently, these parameters are of primary concern to the composters in this area. In efforts to improve product quality to meet standards, composters frequently blend available high carbon by-products such as cotton burs, peanuts hulls, sawdust and wood chips with existing compost materials. Blend ratios of 80:20 to 75:25 compost:organic amendment are commonly used to modify low quality composts to meet minimum TX DOT standards for GUC. Use of higher levels of carbon, e.g. 50:50 blend of compost:organic amendment, could result in better end products but are considered by the composters to be uneconomical due to limited availability and costs (purchase price, transportation, handling) of acceptable carbon sources.

Organic matter**:** The mean organic matter content of the four composts used in this study was 9.8%. Addition of the 10% (v/v) rate of peanut hulls, sawdust and woodchips raised mean organic matter levels to 11.4%, 11.2% and 11.2%, respectively whereas the 30% rates increased the levels to 14.7%, 14.3% and 14.7%, respectively.

Statistically, when comparisons were made *across* compost sources, there were no significant differences in organic matter levels due to the 10% (v/v) applications of peanut hulls, sawdust or wood chips. Significant differences did occur, however, when applications rates were increased to 30% for all treatments, Table 6. Additionally, significant differences were also noted in organic matter levels between the 0 and 30 DAI and 0 and 60 DAI but not between the 30 and 60 DAI sampling periods. The latter findings may indicate that the repeated mixing of the treatments contributed to improved sample homogeneity

When comparisons were made *between* compost facilities, compost sources and organic amendments contributed to significant differences in organic matter levels, Table 6. The composters listed in order of mean increasing organic matter levels are: Composter C = Composter D > Composter A > Composter B with the levels being significantly different except between Composter C and Composter D. All organic amendments applied at the 10 and 30% rates resulted in significantly higher mean organic matter levels over those in the controls, with no discernible differences between the sources (peanut hulls, sawdust and woodchips). As with the *across* compost source comparisons, significant differences in organic matter levels occurred between the 0 and 30 and 0 and 60 DAI sampling dates.

None of the compost or amended compost treatments met the base TX DOT standards for organic matter (25 to 65%) and only compost B consistently met the modified TX DOT standard for organic matter (=10%) before treatments were applied, Tables 2 and 3. Compost A met the minimal organic matter standard following the addition of 10 and 30% rates of the 3-high carbon amendments. In contrast, the 30% rates of the three amendments were required to meet the standard with composts C and D. Either through testing, experience or both, composters are typically able to modify low quality dairy manure compost with varying amounts organic amendments to meet customer requirements.

pH: High pH readings are a common concern for most facilities that produce dairy manure compost in the Bosque River watershed. The four compost materials used in this study differed significantly in pH (Table 6) but all met the modified TX DOT standard for pH (=9.5). The compost from the Composter C facility was the only product that met the agency's base (=8.5) pH standard. Blending high carbon materials with low quality composts had little effect on pH. When analyzed between compost sources, only the 30% peanut hull treatment resulted in a significant reduction in pH whereas when tested across compost sources, the addition of high carbon sources at either the 10 or 30% levels (v/v) had no significant effects on pH, Table 6.

When the compost materials used in this study were initially collected, the odor of NH_3 (ammonia) was noted but by the time the study was implemented, NH_3 odors were generally not detectable. High pH may result from the presence of ammonia nitrogen (NH_3) in compost due to non-uniform and incomplete composting of the dairy manure feed stock. As composting methods improve (via smaller and more manageable windrows, more frequent and more thorough turning/mixing of manure/compost, screening, etc.) high pH due to excess NH_3 is less likely to occur.

Nutrients, Soluble Salts

Composts are generally recognized as products that are high in organic matter and contain multiple plant nutrients, some of which are complexed with organic constituents and released for plant use over time. Although composts may be beneficial as soil amendments, in the marketplace, they generally must compete with commercial fertilizers as a source of plant nutrients. Of the plant nutrients, nitrogen and phosphorus tend to be the most important for agricultural and horticultural applications. The compost sources used in this study contained approximately 6 to 12 lbs. of N and 5 to 15 lbs. of P_2O_5 per wet ton, respectively. Typically, nitrogen is the most costly and limiting nutrient that is required in greatest quantities by plants. Phosphorus is also essential for plant growth but is generally required in lesser amounts. Both N and P may be become problematic if applications substantially exceed plant needs and soil retention capacities. Nutrients in commercial fertilizers are frequently blended in ratios to meet specific plant needs and applications rates are set accordingly. Because nutrient ratios in composts are "fixed," application rates often must be adjusted to meet plant needs of the most abundant nutrient (i.e. P) and other nutrients (i.e. N) supplemented with commercial fertilizers.

The four compost products used in this study differed significantly in total N but not in total P, Tables 6 and 7. Blending organic amendments with the compost products did not significantly change total N levels with the exception of the 30% peanut hulls treatment, Table 6. Total P levels were not affected by the addition of the high carbon amendments, Table 7.

The compost B product was significantly higher in Ca and Na than the products from the other facilities. Blending organic amendments with the four compost sources had no affect on Ca or Na levels (Table 7) or on soluble salts (Table 6). The Na levels and soluble salt reading, Tables 4 and 5, indicate the compost products tested did not pose a salinity hazard to soils or plants.

Carbon: Nitrogen (C:N) Ratios, Respirometry and Cucumber Bioassays

TMECC guidelines (TMECC, 2000) consider three characteristics is assigning a maturity index for compost: C:N ratio, stability (based on microbial activity determined by respirometry) and phytotoxicity (cucumber bioassays for germination and vigor). Composts with C:N ratios less than or equal to 25:1 are categorized as mature and those with higher C:N ratios are considered immature. Respirometry measures the CO_2 evolution from compost samples and is used to estimate the relative stability (biological activity) of composts. Compost with CO_2 evolution rates of less than or equal to 2-4 mg CO_2/g OM are rated as mature. Cucumber germination percentages of 80-90 % and vigor ratings of 85-95% indicate no phytotoxic effects from the growth media and indicate that composts are mature whereas lower ratings indicate immaturity.

C:N Ratios: Organic carbon determinations were confounded by the limestone rock ($CaCO_3$) fragments contained in the inorganic fraction of all compost sources. To obtain accurate estimates of organic carbon, the SCL and SWFTL used procedures to differentiate between the organic and inorganic carbon (C) contained in the compost samples. SCL used separate tests to determine the level of inorganic C (contained in the $CaCO_3$) in each sample and subtracted that amount from the total C to establish the organic C. The SWFTL utilized a modified Loss on Ignition (LOI) procedure that prevents the loss of inorganic carbon yet achieves full recovery of organic carbon (Pitt, et. al., 2003).

C:N ratios of the compost products used in this study ranged from 13 to 15, Table 2 and differed significantly between compost sources, Table 7. Blending the three organic amendments at the 10 and 30% rates tended to numerically increase the C:N ratios in all compost sources. However, only the 30% levels of peanut hulls, sawdust and wood chips resulted in significantly higher C:N ratios (Table 7) which ranged from 15 to 19, Table 4.

Respirometry: Carbon dioxide evolution rates were less than 2 mg CO_2/gm OM for all compost sources, Table 2. Mixing the organic amendments with the composts had no appreciable effect on respiration with the exception of compost C amended with 10% and 30% (v/v) peanut hulls, Table 4. It is possible the higher respiration rates (3.8 to 6.8 mg CO_2/ g OM) and the somewhat higher C:N ratios were related to the maturity of compost material selected for preparing these 6-samples, thus reflecting the variability which exits in these compost sources.

Cucumber Bioassays: The germination percentages for cucumber seed planted in the 4-compost sources ranged from 80 to 100 (with one exception) and the vigor ratings (again with one exception) from 80 to 100%, Table 2. Of the 2-sets of cucumber seed planted in two samples of Compost B, one failed to produce any seedlings (0% germination) whereas all the seed germinated in the other sample. Also, one of the two sets of seedlings planted in Compost D was not rated for germination due to excessive mold growth on the media and poor condition of the seedlings (which received a 0% vigor rating); seedlings in the companion sample exhibited 80% germination and 100% vigor.

The mold problem persisted even after high carbon materials were blended with the 4-compost sources. Of the samples collected 0 DAI and 30 DAI, 21% and 25%, respectively, were not rated for germination because of excessive mold growth. Two-thirds (66.67%) of the moldy samples occurred in the treatment samples (control, 10% and 30% organic amendments) prepared with compost D, suggesting that seedling disease organism survived the composting process in this lot of dairy manure.

Due to the missing germination ratings, only the cucumber seedling vigor data were statistically analyzed. When compared between compost sources, the treatments prepared with Compost D had significantly lower vigor rating, Table 7. Cucumber seedling vigor ratings were also significantly different for the 0 and 30 DAI sampling dates when tested between and across compost sources.

The combined C:N ratios, respirometery and cucumber bioassay ratings indicate that the 4-compost sources can be classified as mature but that classification is confounded by the variability that seems to exist in one or more of the compost products.

Laboratory Comparison

Due to differences in dairy manure feedstocks, manure storage and handling procedures, composting methods and other factors, the chemical, physical and biological properties of dairy manure composts are highly variable. Standardized testing procedures are needed to provide composters and users with a means for assessing compost quality to determine if the end product meets specific needs. Test results may establish the need for further processing (i.e. adding organic amendments; producing alternate products such as CMT), suitability for specific applications (i.e. top-dressing sports fields), rates at which the products should be used for one or more applications (i.e. soil amendment; crop fertilization) and as a basis for pricing products.

The U.S. Composting Council has endorsed the TMECC through its STA program. Laboratories seeking STA certification must invest in equipment and personnel training to meet QA/QC testing standards set by the Council. The STA program ensures testing uniformity but analytical costs are relatively expensive due to QA/QC requirements, equipment and personnel expenses, the often small and variable volume of samples generated by the compost industry, and the variability in types of analyses requested per sample. In contrast, service laboratories, such as the TCE-SWFTL, are structured to process large numbers of soil, plant, water, manure/compost and other samples and to offer more "analytical packages" than specific analyses for individual samples. Test results are used to make research based recommendations relating to crop fertilization needs, forage and hay quality, suitability of water for irrigation, etc. Because of the high throughput, analytical costs are less expensive than those charged by labs adhering to strict (TMECC) procedures.

The analytical tests performed by the SCL and SWFTL are listed in Table 1, and the results of the analyses conducted on the 84 treatments samples are shown in Tables 4 and 5, respectively. With the exception of organic matter, there were significant differences (at the 95% level) in the nutrient levels (N, P, Ca and Na), pH and soluble salts determined by the two laboratories, Table 8. For organic matter, there were no significant differences between labs even though two distinct procedures were used to estimate organic carbon levels in the samples. Higher order interactions were detected between organic matter levels and carbon sources, labs X carbon sources and sampling dates (according to GLM model but not Split Plot-Mixed design model; data not shown in Table 8). Higher order lab X carbon interaction was also noted for soluble salts and lab X day interactions for pH and Na.

Numerically, the mean SWFTL readings were higher for N (7.6%), P (14.8%), Na (59.3%), pH (1%), soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%) than the mean readings obtained by the SCL, Figure 1. SWFTL managers were aware of, and were in the process of correcting, contamination problems which resulted in abnormally high Na readings. The other variations may reflect differences in precision, accuracy and bias of the methods used.

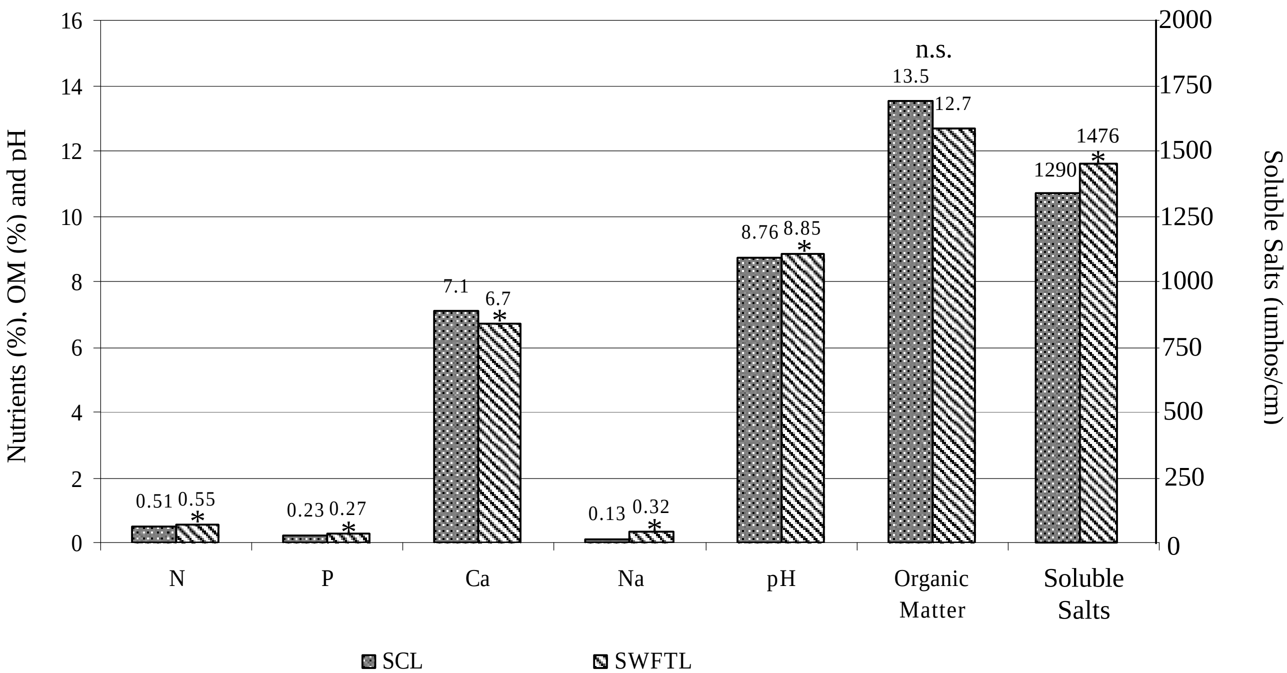
Although composters and retailers are often required to use TMECC results provided by STA certified laboratories in marketing compost products to certain entities, service laboratories such as the TCE-SWFTL can provide good assessments of compost quality at a fraction of the cost. The results of this comparison indicates composters could effectively use data provided by SWFTL as management decision aids (i.e. amending manures or composts with high carbon materials) and in assessing the quality and potential applications of their products (i.e. GUC, CMT).

Table 8. Comparison of compost test results obtained by the Soil Control Lab and the Soil, Water and Forage Testing Laboratory determined by Analysis of Variance using split plot application of a repeated measure design

Comparison	Total N	Total P	Total Ca	Total Na	pH	Soluble Salts	Organic Matter
	---Across compost sources---						
Laboratories	*	*	*	*	*	*	n.s.
Carbon sources/volumes	n.s.	n.s.	n.s.	n.s.	n.s.	*	*
Sampling Dates	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lab X Carbon	*	n.s.	n.s.	n.s.	n.s.	*	*
Lab X Day	n.s.	n.s.	n.s.	*	*	n.s.	n.s.
Carbon X Day	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lab X Carbon X Day	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* significant difference at 95% confidence level

Figure 1. Comparison of mean values for several parameters determined in four compost sources by a laboratory using TMECC methodologies and by a service laboratory using alternate methods. (* indicates significance)



Conclusions

The compost industry in the North Bosque River watershed has made substantial progress in improving the quality of the composts it produces from dairy manure. In the early stages, the manures obtained from dairies frequently contained excessive extraneous materials (bedding sand, limestone fragments), were stored in large, difficult to manage windrows or stockpiles, and often were not properly composted. As a consequence some of the resulting products were of low quality, not readily marketable and consequently, were stockpiled for two or more years. Options for utilization of these stockpiled products included incorporating their use in production of CMT and ECC materials, in farm and ranch applications, and in improving their quality through screening, grinding and/or the addition of high carbon amendments. Although the latter option increased production costs, amended products can often be improved to meet standards and to be sold as GUC.

In this study, significant differences existed in organic matter contents, pH, total N and C:N ratios between the four compost sources tested. Significant differences in organic matter, P, Ca, and Na levels, pH and cucumber seedling vigor occurred due to sampling date (0 and 30 DAI). This indicates high degrees of variation existed within the individual lots of compost. Adding 10% and 30% (v/v basis) of three high carbon materials resulted in significantly higher organic matter levels when analyzed between the four compost sources but only the higher (30%) rates of the amendments increased organic matter contents across compost sources. Of the treatments applied, only the 30% rate of peanut hulls resulted in a significant decrease in pH and in a significant increase in total N between compost sources; no significant effects for these parameters occurred across compost sources. Addition of the organic amendments had no consistent effects on P, Ca, Na, soluble salts or on cucumber seedling vigor between or across compost sources.

Results of this study showed that physical mixing of 10 to 30% (v/v) 3-high carbon amendments (peanut hulls, sawdust and wood chips) with 4-low quality dairy manure composts can increase organic matter content and alter C:N ratios but will have limited effects on pH, soluble salts and nutrients. With the exception of the 30% rate of peanut hulls (which significantly lowered pH and increased total N between compost sources), carbon sources had no significant impacts on the parameters tested between or across compost sources. When considered across all compost sources and high carbon amendments, adding 10 and 30% of the amendments to the composts increased the mean organic levels from approximately 9.8% to 11.3% and 14.6%, respectively. On average, the blended materials met the modified (>10%) but not the base (25-65%) TX DOT specification for organic matter content. If adding higher rates of the amendments are cost prohibitive, a better application of low quality composts may be their use in the preparation of CMTs or ECCs. Other studies have shown blending high carbon constituents with dairy manure prior to composting (Michel, et al, 2005) is also a viable option for improving compost quality.

TMECC have been adopted as the industry standards for compost testing by STA certified laboratories. Defining manure and compost quality through laboratory analysis can serve as a marketing tool and also as a valuable decision aid for compost facility managers. Cost and time requirement to obtain TMECC results have limited reliance on laboratory testing by compost facility managers. Service laboratories such as the TCE SWFTL often offer “analytical packages” for manure/compost testing at lower costs. Although services labs typically adhere to specific QA/QC standards, many are not STA certified for running TMECC procedures. A comparison of compost test results provided by SCL, a STA-TMECC certified facility and the TCE-SWFT lab showed that the values for selected nutrients (total N, P, Ca and Na), pH and soluble salts differed significantly between the two laboratories but there were no differences in organic matter levels. Numerically, the mean values obtained by SWFTL were higher for N (7.6%), P (14.8%), Na (59.3%), pH (1%), soluble salts (12.6%) and were lower for Ca (5.6%) and organic matter (5.9%), Figure 1. The difference in Na is attributed to a contamination problem that occurred at the time these analyses were conducted. Composters and retailers are often required to provide STA-TMECC results in marketing their products to provide users with information that can be used to equitably compare product qualities, determine use rates, etc. Service laboratories can also be effectively used to provide compost facility operators with low cost preliminary assessments of manure of compost qualities for use as management decision aids.

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