The Economic Potential of Composting Breeder and Pullet Litter with Eggshell Waste

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Abstract

Expansion of the wastes coordinated by the Ozark Poultry Litter Bank is needed. This study examined a method of combining low value poultry wastes to produce compost. Analyses of four compost blends and two hypothetical production systems provide entrepreneurs with the production and financial information to make informed decisions.

Key Words: composting; poultry industry; waste management; product development

JEL: Q53, Q13, Q16

BACKGROUND

Poultry production is highly concentrated in the Ozark Plateau region. A byproduct of this concentration is large volumes of poultry litter. Land application of litter has long been known to increase agricultural output; however, a negative externality of land applied litter is agricultural runoff. Recently, phosphorus (P) runoff has become a concern in area watersheds prompting researchers to identify alternative methods of litter disposal. A substantial number of growers will need to utilize alternative litter management practices to satisfy regulatory guidelines nutrient application in nutrient surplus watersheds (Goodwin, H.L., Hipp, and J., Wimberly, J. 2000). One attractive option is the non-profit corporation BMPs, Inc. established in March of 2005 to coordinate pick-up and transportation of litter from producers in nutrient surplus watersheds and distribute it to users located in areas where excess nutrient loads are not problematic. Broiler and turkey litter have been the focus of export thus far. To date limited outlets for hen and pullet litter (lower in nutrient value and more difficult to transport) exist.

Approximately 55,000 tons of breeder hen and pullet litter were generated in the ESW and IRW in 2004 (Goodwin et. al 2005). Another byproduct of the poultry industry is eggshell waste from area breaking plants, most of which is currently land filled. This waste consists primarily of calcium carbonate ($CaCO_3$); calcium (Ca) is typically thought of as a means of correcting soil acidity but is also an essential plant nutrient. High-quality compost can have a large impact on soil quality and in certain markets (golf courses, landscaping, horticulture) there may exist great market potential for such compost. However, entrepreneurs should have production and financial information to make informed decisions before starting a compost facility. This study focuses on providing potential operators with: 1) four potential blends to combine breeder hen and pullet litter with eggshells and other common composting inputs and 2) budgets for two hypothetical compost production facilities.

OBJECTIVES

The overall objective of this study is to identify an effective method of composting breeder hen and pullet litter with eggshell waste and other waste inputs into a marketable product. Four product blends were designed and inputs combined accordingly and composting production cycle is complete. Through laboratory analysis at BBC Labs in Tempe, Arizona the quality[1] (microbial concentration, diversity, maturity and stability) of each respective blend was assessed. Two hypothetical compost facilities were modeled in order to provide production budgets for potential operators. The results of each objective contribute to the economic assessment of producing compost with poultry wastes typically thought of as low value.

METHODS

Recipes for each blend were designed based on typical carbon (C) and nitrogen (N) (C:N) ratios, moisture levels and structure ratings (airflow potential) of all inputs. Each blend had a beginning C:N ratio of near 30 and moisture levels kept near 50 percent during the composting process. The highly controlled Advanced Composting System (ACS) of Midwest Bio-Systems, Inc. (MBS, 2006a) and a tractor-pulled compost windrow turner were used to manage each blend. A break-even analysis examines two hypothetical compost production systems utilizing windrow composting. The production systems analyzed are similar to the one used in this study. The System 1 has a capacity of 5,000 tons of input; System 2 a capacity of 20,000 tons of input.

Inputs

Eggshell waste, breeder and pullet litter, hay, oak sawdust, unfinished compost and clay (sub-soil) are the primary inputs in the four blends; proportions of each input are varied across the blends. Eggshell waste was obtained through Membrell, LLC in Carthage, Missouri. Prior to delivery the shells were pulverized and dried (< 10 percent moisture) and contained

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[1] University of Arkansas labs are currently in the process of evaluating the nutrient content of the finished compost; unfortunately this analysis is not complete.

approximately 5-10 percent of the protein membrane. The pulverized shells were dense (7.9 tons of shells, about 6.5 cubic yards). Breeder and pullet litter were obtained from nearby contract growers. Square bales of rotten hay (200) were obtained from a local farmer; hay offers a good structure for oxygenation and was selected as the primary carbon source over wood chips because it typically breaks down faster and more completely than wood chips. Unfinished compost (the leftover materials cleaned off of the sides of windrows) provided by Hostetler Composting in Berryville, Arkansas, was added to Blends 2, 3 and 4; this is a typical practice for established compost firms. Clay (sub-soil) was used for its odor reducing properties and its beneficial contribution to building humus soil structure. Water was added during the turning process to maintain moisture levels. The final input to each blend was a combination of three inoculants added at separate stages of the process (the N-Converter, Humifier, and Finisher).

Compost Process

A composting firm in Berryville, AR, was contracted to produce the compost blends designed for this project. The operator provided the site, tractor, compost turner, water wagon, labor, and some of the inputs used in the blends. Although the combination of inputs in each blend varied, the process for managing each blend was the same. The compost process Advanced Composting System (ACS) of Midwest Bio-Systems used is a highly aerobic and controlled process with quality monitoring throughout. Controls include proper recipe formulation and aeration and moisture decisions based on readings of temperature, CO_2, and moisture. The ideal C:N ratio for compost at the start is in the range of 25-30 and moisture content should be kept between 40 and 50 percent. Temperatures are primarily controlled by the C:N ratio and should range from 131° to 150° F (55 - 66° C) for at least 2 weeks and progressively decline.

Step one, materials delivery and preparation, is most successful if all materials are at appropriate moisture levels and consistencies. Different materials decompose at different rates.

By windrowing, turning and watering (when dry) inputs before combining, inputs should break down similarly once combined in the windrow. The synchronized break down of materials should reduce the time required to finish the compost cycle and increase saleable output.

All materials (except eggshells) were combined into windrows during weeks 1 thru 3 and windrows were turned daily[2]. By week 2 Membrell, LLC, in Carthage, MO agreed to deliver eggshells to the project site; however, the material had very low moisture content (< 10 percent) than the original eggshells to be used. The delay meant windrows had been kept at sub-optimal moisture levels for too long and some windrow inputs, mostly the hay, became too dry and stopped decomposing. During week 3 the eggshells, clay and first application of inoculants (N-Converter) were incorporated into each blend according to each recipe. The N-Converter should improve compost quality and increase the microbial population and diversity was added at this point because this is the portion of the composting production cycle where most of the breaking down of matter occurs. Organic matter is broken down during this portion by microbial processes and their resulting heat. N is converted from ammonia (NH3) to nitrates (NO3). The N-Converter contains specific microbes best suited to break down organic matter and convert the ammonia from nitrites to nitrates.

Windrows were then re-combined into shorter, taller rows. Rows were rebuilt to maximize site space and to retain heat in each row; over the first three weeks a great deal of volume was lost in each row. During weeks 4 thru 6, the windrows were turned every second or third day, unless weather dictated otherwise. During week 6, during the primary humus build-up portion of the compost production cycle, the second portion of the inoculants, the Humifier, was added in a split application. The Humifier provides microbial species that help to build the

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[2] For the first two weeks, each blend was kept below ideal moisture because the original eggshells were to be 50 percent moistureThis was planned to only last for four days; however, the trucking company contracted to haul eggshells for the project was unable to do so.

broken down organic matter into these humic substances while increasing the overall microbial population diversity of the finished compost.

During weeks 7 thru 9, activities slowed. The compost was turned only twice during week 7, once during weeks 8 and 9 and the final portion of the inoculants were added (Finisher). The Finisher was added at this point because the compost should be in the stabilization portion of the production cycle. The Finisher provides microbial species that help to continue to build humus soil structure, stabilize any remaining volatile compounds and further adding to the microbial population and to its diversity.

During weeks 10 and 11 activity at the site was limited to curing and sampling. Due to the delay in adding eggshells, there were sufficient materials continuing to breakdown to produce heat and CO_2. The compost was allowed to "cure" for two weeks under cover with turning done only once per week. During week 11, two samples of each blend were taken and shipped to BBC Labs for the compost quality analysis portion of the study. Each of the eight samples was made up of 10-12 sub-samples totaling approximately 2 quarts of total material per sample. The design or "recipe" used in each blend is described in table 1.

Laboratory Analysis

Nutrient Analysis

A University of Arkansas lab is processing samples for the nutrient analyses; results are pending. Analysis will include water, soil pH, extractable soil nutrients (Ca, Mg, Na, K, Fe, Mn, Zn, Cu, B, S, and P), and soil electrical conductivity. Soluble soil nitrate-N and the amount of organic matter present will also be tested. The analysis will include an estimate of the final C:N ratio and moisture level and quantify the presence of metals. A summary of the estimated C:N ratio, and the N, P, K and Ca for each blend based on typical nutrient contents of the inputs used in each blend can be found in table 1.

Compost Quality Analysis

BBC Labs performed three microbial tests for 1) functional group enumeration and diversity analysis; 2) stability analysis and 3) maturity analysis. The combination of all three analyses provides the “big picture” of the state of each compost blend. In addition, pathogen testing for E. coli and Salmonella were done. Table 2 includes information on the optimal ranges and ideal values for each of the quality components as well as pathogen limits.

The functional group enumeration analysis indicates the number of viable microorganisms in a particular group. The six functional groups are summarized in table 2. The diversity analysis estimates the total number of different types of microbes in each category. The Maturity analysis refers to plant toxicity associated with the compost. Immature composts contain more growth-inhibiting substances than mature composts and include salts, ammonia, phenolic substances, heavy metals and organic acids. Stability analysis refers to the degree to which composts have been decomposed into more stable materials by measuring the amounts of carbon dioxide produced or oxygen per unit per hour utilized under conditions appropriate for microbial growth. More stable compost will have lower respiration rates than unstable compost (table 2) (Wilson and Dalmat, 1986).

Break-Even Analysis

Entrepreneurs need production and financial information to make informed decisions. Costs required for producing each compost blend include the total input costs, total capital investment cost (land and improvement, equipment, etc.), the annual fixed[3] (ownership) costs and the hourly variable (operating) costs. Two hypothetical compost systems were designed in the BE analysis based on two objectives: 1) to minimize capital investment, production costs and time required and 2) to maximize usable output. System 1 is a small scale facility with 5,000 tons (of inputs) capacity and a 12-ft wide windrow turner; System 2 is a large scale facility with

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[3] Fixed costs are estimated before interest and tax.

20,000 tons (of inputs) capacity and a 17-ft. Both systems screen all of the finished compost and sell the product in bulk; System 2 was assumed to bag 25 percent of its compost into 2 cu. ft. bags. Production budgets were generated from these systems to provide useful information to entrepreneurs interested in starting a composting operation.

The composting systems were patterned after existing commercial operations (such as the one used to produce the four blends) producing moderate to high quality compost suitable for a range of applications. Other information was synthesized from estimates made in previous studies of compost production systems (Haith, et al., 2001; MBS, 2006b; Safley and Safley, Jr., 1990). Each system includes: 1) land requirements 2) production schedule 3) a sketch of the production area layout as well as the materials preparation area, retention pond and buildings (if required) 4) a list of machinery and equipment requirements; 5) labor and equipment requirements; and 6) production budgets summarized all of the capital, fixed costs and variable costs required.

Major cost items a compost production facility would need to produce compost are included but some overhead items such as office, machinery, supplies, legal services and marketing costs were omitted, as were interest and taxes. These costs can represent a substantial portion of a firm's budget depending on various factors. Entrepreneurs should be aware of the costs excluded in this study.

Table 3 summarizes the capital and land requirements, useful life, purchase price and cost estimates for all components used in this study. The compost production cycle was assumed to be 6 months long with 3 months required for storage and curing; compost sales, delivery, marketing and feedstock contracting, delivery, and preparation would be annual activities. Each windrow was assumed to be turned 30 times before being covered for curing. Nine weeks were required to complete a batch and all rows were combined at the end of the third week (2 rows combined into 1) and new windrows were formed at the same time, which results in 19 rows completed per acre during the 6 month season. Equipment used to produce the compost is assumed to operate at 90 percent efficiency[4] (Haith, et al., 2001; MBS, 2006b ; Safley and Safley, Jr., 1990). Land was assumed to have a purchase price of $2,050 per acre (NASS, 2006) and improvements could be constructed for $7,200[5] per acre. Annual fixed costs included were straight line depreciation on land improvements and machinery and equipment, general overhead items license and permitting, repair and maintenance, testing, and insurance.

Variable costs included those that vary with the output volume. Variable costs were based on equipment output capacities, production schedules and for System 1 all of the output was assumed to be sold in bulk while for System 2 - 25 percent was bagged[6]. Material costs included hay (rotten), oak sawdust, unfinished compost, breeder litter, pullet litter, eggshells, clay (sub-soil), inoculants, and bags. Hay costs assume the hay was rotten or spoiled and can be obtained at a discounted price equaling 10 percent of the average hay price ($6.20 per ton[7]) plus $4.00 per ton hauling fee. Sawdust was assumed to cost $19.22 per ton[8]. Unfinished compost was assumed to be located on site and has zero material cost because the costs to produce this material are accounted for in the variable costs of producing it. Breeder and Pullet litter is budgeted at a cost of $4.00 per ton for transportation and $6.00 per ton cleanout fee (Goodwin, 2006). Eggshell waste was assumed transportation cost of $6.17 per ton; this cost was observed in delivery of materials for the four blends. Clay was budgeted at $0.91 per ton. The inoculants required were budgeted at $0.425 per cu yd[9] and bags $0.33 per bag[10].

Variable machinery and equipment costs include fuel, lubricants and repair expenses (Haith, et al., 2001; and Safley and Safley, Jr., 1990). Costs estimates were updated using 2005

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[4] In practice, operating at 100 percent efficiency is not realistic given variations in weather, feedstock availability, and timing of compost sales and delivery. The authors use 90 percent efficiency to allow for unforeseen circumstances that would not allow the "ideal" production cycle to be fulfilled.

[5] From Safley and Safley, Jr. (1990) adjusted to current dollars

[6] To account for the decrease in volume, a 9.2 percent reduction loss factor was assumed for both systems.

[7] Average hay price for all hay is from NASS (2006b).

[8] From Safley and Safley, Jr. (1990) updated to 2005 dollars; includes hauling costs.

[9] $425 for inoculants pack (MBS, 2006b) and is enough to treat 1,000 cu yds.

[10] From Safley and Safley, Jr. (1990) updated to 2005 dollars.

Prices Paid Indices from the National Agricultural Statistics Service (NASS, 2006c). Hourly labor was budgeted at $12.23 per hour and was obtained from the Bureau of Labor Statistics and the mean value for all farming, fishing, and forestry occupations was used (BLS, 2006). System 2 was assumed to require a full-time manager to supervise and monitor the compost production facility and to implement marketing plans; a $43,270[11] salary was assumed. The specific requirements and costs estimates for each system are found in following sections.

COMPOST PROCESS RESULTS

The primary measures for monitoring the composting process were temperature, CO_2 production and removal and moisture. Moisture management was done simply by daily inspection of each blend with the moisture being kept between 45 to 50 percent. Figures 1 and 2 show the weekly average temperatures (before turning) and weekly average CO_2 readings (before and after turning). The observed temperatures (all in degrees F) of each blend were different followed a similar trend throughout the compost cycle (figure 1). Each blend had a temperature of greater than 150^o for the first two weeks, declining thereafter. During week three the average temperatures ranged from 137^o to 144^o; week four temperatures declined to 115^o to 128^o. During week five, however, temperature remained fairly constant. Near the end of week four the windrows were reconfigured to help retain heat and allow for better utilization of the compost site. Temperatures during week five (115^o to 130^o) indicated this strategy was successful[12]. During subsequent weeks, average temperatures continued to decline; by week nine all blends had temperatures 85^o and 96^o and by week eleven, during the curing phase, all blends temperatures were in the ideal range.

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[11] Mean value for "First-Line Supervisors/Managers of Farming, Fishing, and Forestry Workers" from BLS (2006).

[12] Two windrows at the same stage of the production cycle are typically combined when volume has reduced. This allows for the production facility to be used for more production by utilizing less space. Instead of combining windrows (since each windrow is a different blend) each blend was simply folded on top of itself to create a windrow with half the length but twice the height. At this point, the same volume was being produced on half the area.

The average weekly CO_2 readings (figure 2) indicated microbial population in each blend was thriving and breaking down materials. CO_2 readings are taken before turning and indicate whether aerobic breakdown is being accomplished. Low readings ($\leq$ 4) could indicate a problem, possibly that anaerobic conditions have been established. The average CO_2 during week 1 ranged from 13 to 17 percent, indicating sufficient airflow to provide oxygen (O_2) to the microbes so materials could be broken down. During weeks 2 to 5, average weekly CO_2 readings remained between 15 and 20 percent. Readings on October 30th were very low (6, 4, 6, and 11 percent for Blends 1 thru 4, respectively). On this day, between uncovering the windrows and starting to turn the windrows, the wind might have replaced the CO_2 with O_2 before an accurate reading could be taken. The following day, readings for all rows were above 20 percent so the readings from October 30th were considered errant and removed from the calculation of average weekly temperature for week 5. Average weekly temperatures for week 6 ranged from 18 to 21 percent. Readings from week 8 indicated that CO_2 production was subsiding to levels below 10 percent. By week 10 each blend was in the ideal range for finished compost (< 8 percent).

LABORATORY RESULTS

Nutrient Analysis Results

Table 1 shows estimates of nutrient content and equivalent fertilizer values for each blend based upon the inputs used. These values will likely not reflect the finished compost nutrient analysis. Nitrogen conversion during the materials build-up phase of the compost production cycle should lead to higher values. Data used to estimate the nutrient contents in table 1 are average values and may vary with the inputs used here.

Compost Quality Analysis Results

Results of the compost quality analysis are summarized in table 2. Each blend was sampled twice and the results from each sample were combined to find a mean value for each.

All blends tested positive for E. coli but all are within acceptable state limits (Arkansas Pollution Control and Ecology Commission, 2006). The lowest levels of E. coli were found in Blends 3 and 4. Salmonella tests were negative for all blends.

All blends fell within optimal ranges of microbial species enumeration except for the ratio of aerobic to anaerobic bacteria; only Blend 4 was within the optimal value for this parameter. The most aerobic bacteria were found in Blend 4 but all blends' values fell within the optimal range. Blend 2 had the highest measure of yeasts and molds (fungi). Nitrogen-fixing bacteria populations were the highest in Blend 1, Blend 3 had the most actinomycetes and Blend 4 had the highest level of pseudomonads, important in helping plants make phosphorus available.

Total species diversity values for each blend fell within the moderate diversity range ($3 < d < 6.5$). The highest diversity value (6.2) was associated with Blend 4 and Blend 3 had the lowest. Each blend had high diversity values for yeasts and molds, pseudomonads, and N-fixing bacteria while the other three functional groups diversity values fell into the moderate or low range. The maturity analysis results in table 2 indicated that all blends were not yet mature (index < 50 percent) although Blend 4 approaches the ideal range. These results were expected as the blends need to cure for several more weeks before use. After allowing all blends to cure properly, each should be within acceptable levels of maturity. Accordingly, the stability analysis (respiration rate) results indicated that none of the blends were ready for use in horticultural applications but could be used in field applications. Blend 2 was the most stable with Blend was the most unstable; however, all blends have values of less than 35 mg O_2/Kg.

These compost quality analysis results indicate that despite the coordination problems experienced early in the production cycle, moderate to high quality levels of compost were produced. Based on these results it is not possible to determine which blend is the highest quality blend. These results do indicate that if maturity and stability results improve over the curing stage as anticipated then all combinations of inputs and methods used to produce each blend resulted in high quality compost.

BREAK-EVEN ANALYSIS RESULTS

System 1

System 1 has an annual input capacity of 5,000 tons; 453 tons of hay, 162 tons of sawdust and 252 tons of unfinished compost; 1,035 tons of breeder litter, 1,359 tons of pullet litter and 159 tons of eggshells; and 1,581 tons of clay were used to produce the compost[13]. Finished product was assumed to total 4,540 tons or 6,053 cubic yards. All output was assumed to be screened and sold in bulk form. System 1 required 2.48 acres of land; 2.05 acres for compost production; 0.25 for materials storage and preparation; and 0.18 acres for a runoff retention pond (table 3). Windrows were formed and compost was produced on hard packed bare ground. Piles were formed with a front-end loader (60 HP) and a tractor (85 HP) and a 12-ft windrow turner. Rows were turned at total of 30 times each. A capital investment[14] of $141,586 was required with the largest expenditure made for the 85 HP tractor ($42,250). Capital costs per ton of finished compost were $31.19 (table 3). Total annual fixed costs were $12,629 with the largest costs associated with the depreciation cost of machinery and equipment (58.6 percent of total).

Annual variable costs were made up of materials cost, power requirements for machinery and equipment and labor required to accomplish the production cycle. Cost of materials for totaled $36,657 which represented 54.9 percent of total variable costs (table 3). Power requirements were the estimated time and power needed to complete all activities at the facility (tractor hours for instance). Annual labor requirements were estimated using a factor of 1.2 (power requirements multiplied by 1.2 to estimate labor). This “labor” factor was used to account for the additional time required for job preparation, repair and maintenance, breaks and

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[13] Blend 3 is analyzed in the break-even analysis. This blend would likely have the highest nutrient content and would dispose of the highest amount of poultry litter. Only one blend is discussed to shorten the presentation.

[14] System 1 is assumed to rent the 70 cu yd/hr screening machine.

transport time around the site. Cost of power estimates for machinery and equipment totaled $18,872 and 917.1 hours of labor at $12.23 per hour totaled $11,216 in labor costs. 637.5 hours per season were required to turn the windrows, 109.1 to build the windrows, 122.1 required to screen and prepare for storage and 48.4 hours required to combine all windrows (at week 3, for each respective row). Total variable costs for System 1 were $66,745. The total cost for System one was $17.48 per ton of finished compost.

System 2

System 2 has an annual input capacity of 20,000 tons; 1,811 tons of hay, 647 tons of sawdust and 1,006 tons of unfinished compost; 4,140 tons of breeder litter, 5,436 tons of pullet litter and 635 tons of eggshells; and 6,325 tons of clay were used to produce the compost. Finished product was assumed to total 18,160 tons or 24,213 cubic yards. All output was assumed to be screened and 75 percent sold in bulk form and 25 percent bagged in 2 cu ft bags. System 2 required 6.42 acres of land; 4.83 acres for compost production; 0.58 for materials storage and preparation; 0.57 acres for two buildings (bagged compost and equipment storage building and screening and bagging building) and 0.43 acres for a runoff retention pond (table 3). Windrows were formed and compost was produced on hard packed bare ground. Buildings required asphalt pavement floors. Rows were formed with two front-end loaders (60 HP and 135 HP) and a tractor (140 HP) and a 17-ft windrow turner. Rows were turned at total of 30 times each. A capital investment of $780,898 was required with the largest expenditure made for the screening machine ($129,750)[15]. Capital costs per ton of finished compost were $43.00 (table 3). Total annual fixed costs were $115,353 with the largest costs associated with general overhead $61,950 (53.7 percent of total). One full time manager would be employed; this is the largest component of the general overhead.

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[15] Screening machine ownership would be required by 1) total time required and 2) frequency of screening.

Annual variable costs were made up of materials cost, power requirements for machinery and equipment and labor required to accomplish the production cycle. Cost of materials for System 2 totaled $171,341 which represented 68.7 percent of total variable costs (table 3). Again, annual labor requirements were estimated using a factor of 1.2. Cost of power estimates for machinery and equipment totaled $49,533 and 2,334.4 hours of labor at $12.23 per hour totaled $28,550 in labor costs. 1,262.6 hours per season were required to turn the windrows, 217.9 to build the windrows, 757.1 hours required to screen, bag, stockpile and store compost and 96.9 hours required to combine all windrows. Total variable costs were $249,424 and the total cost was $20.09 per ton of finished compost (table 3).

SUMMARY

Composting breeder and pullet litter with eggshell waste could be a viable method of generating a marketable product with these particular wastes. Results presented indicate the methods used to produce the four compost blends in this study resulted in a moderate to high quality product. Proper material delivery and preparation would increase the quality of all blends produced, *ceteris paribus*. Further curing of all blends should lead to higher quality compost than indicated herein. Break-Even analyses show that compost can be produced at a cost of $17.48 to $20.09 per ton based on the observed values and assumptions made for Systems 1 and 2, respectively. The combined results of the quality and Break-Even analysis provide entrepreneurs in the region with the production and financial information needed to make an informed decision about producing compost.

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Table 1. Input Quantities, C:N Ratios, and Estimated Nutrient Content for Each Blend

Material	Blend 1		Blend 2		Blend 3		Blend 4	
	Percent (%) of Row		Percent (%) of Row		Percent (%) of Row		Percent (%) of Row	
	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight
Carbon Source								
Hay (Rotten)	40	11	33	9	32	9	40	10
Sawdust, Oak	7	4	7	4	5	3	7	4
Compost, Unfinished	0	0	7	6	5	5	7	6
Nitrogen Source								
Manure, Breeder	13	16	13	16	16	21	7	8
Manure, Pullet	24	20	24	19	31	27	19	15
Mineral Source								
Egg Shells	4	11	4	11	1	3	7	22
Other								
Clay Sub-Soil	13	38	13	36	11	32	13	36
Total Volume (cu yds)	42		42		52		41	
Total Weight (tons)		16		17		19		17
C:N Ratio	32		32		30		32	
Estimated Nutrients	lbs	lb/ton compost	lbs	lb/ton compost	lbs	lb/ton compost	lbs	lb/ton compost
N (lb)	244	17	258	17	399	23	171	11
P (lb)	336	23	355	23	547	31	232	15
K (lb)	241	16	255	17	393	22	169	11
Ca (lb)	3,569	242	3,773	245	1,840	105	6,839	441
Commercial Fertilizer	Total ($)	Per Ton ($)	Total ($)	Per Ton ($)	Total ($)	Per Ton	Total ($)	Per Ton
Equivalent Value ($)	279.82	19.14	295.82	19.38	416.65	23.71	238.46	15.4

Note: Nutrient content based on inputs; finished compost nutrient analysis pending. Fertilizer equivalent values include the N P K and Ca content of the compost. This represents only a fraction of the total value of compost.

Table 2. Compost Quality Analysis for Each Blend (Based on Mean Values)

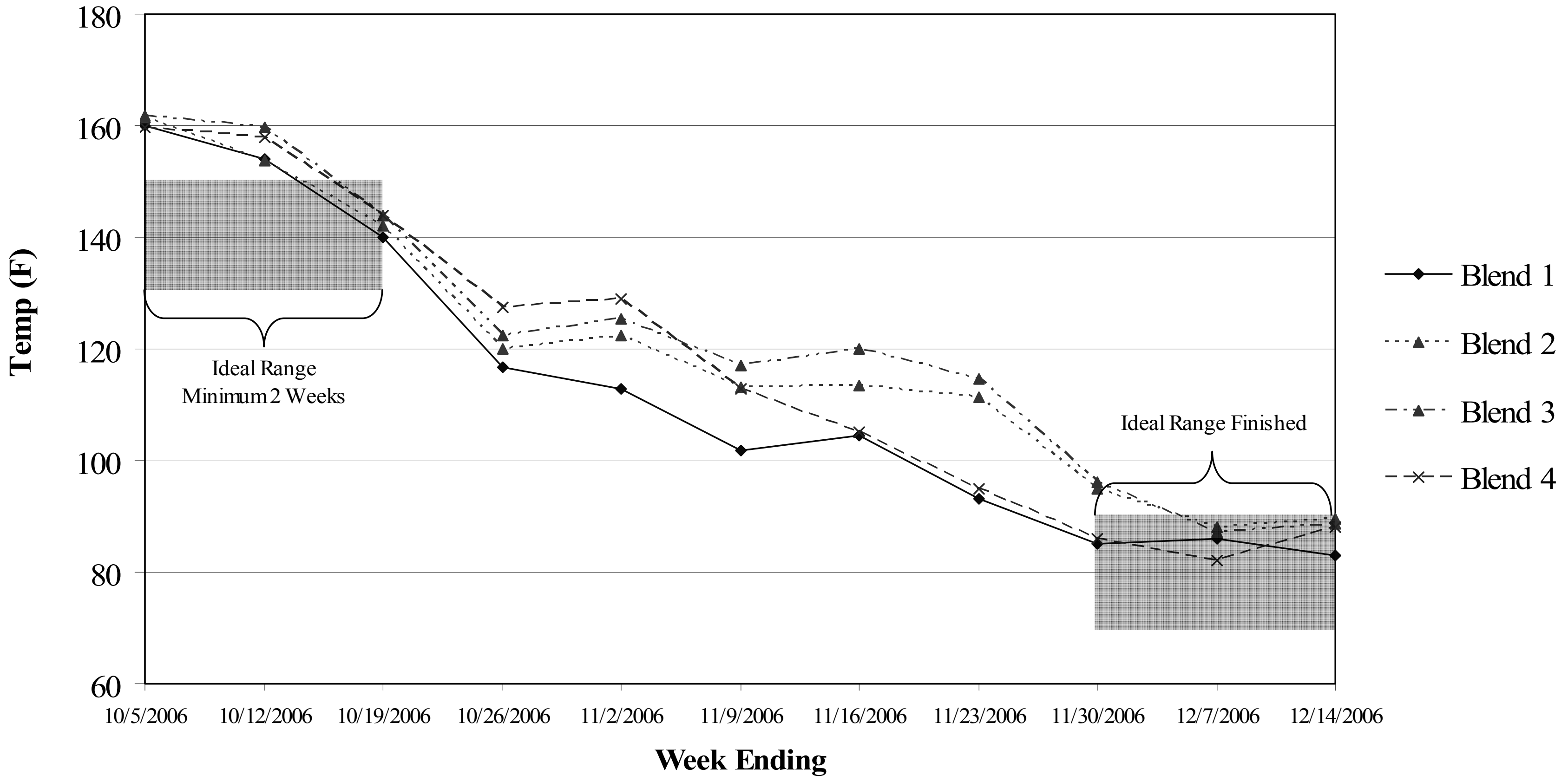
				Blend 1		**Blend 2**		**Blend 3**		**Blend 4**	
Pathogen Screening	**Limit**			**Detection**	**Level**	**Detection**	**Level**	**Detection**	**Level**	**Detection**	**Level**
E. coli (1-23 MPN/g)	< 1000 MPN/g			Positive	>23 MPN/g	Positive	11 MPN/g	Positive	3 MPN/g	Positive	2 MPN/g
Salmonella (1/4g)	< 3/4 per g			Negative	<1/4 g	Negative	<1/4 g	Negative	<1/4 g	Negative	<1/4 g
Six Functional Groups	**Description**	**Optimal Ranges**	**Moderate Diversity**	**Enumeration**	**Diversity**	**Enumeration**	**Diversity**	**Enumeration**	**Diversity**	**Enumeration**	**Diversity**
Aerobic Bacteria	Composts with less than 100 million CFU/gdw will not perform as well as soil inoculants and may not be effective in suppressing plant diseases.	100M - 10B CFU/gdw	1.6	4.5E+09	0.9	3.5E+09	0.9	2.7E+09	1.2	7.1E+09	1.0
Anaerobic Bacteria	Overgrowth of anaerobes indicates the compost not turned with sufficient frequency.	≥10:1 Aerobic to Anaerobic	0.8	4.5E+09	0.3	2.1E+08	0.3	1.7E+08	0.3	2.6E+08	0.6
Yeasts and Molds	Important for breaking down organic compounds, soil nutrient cycling, stabilizing soil aggregates, and controlling plant disease.	1K - 100K CFU/gdw	0.8	1.2E+04	2.0	6.4E+03	1.7	5.2E+03	1.1	5.8E+03	2.6
Actinomycetes	Important for the breakdown and nutrient cycling of complex chemical substances, improving soil crumb structure, and assisting in the reduction of plant pathogen pressures.	1M - 100 M CFU/gdw	0.9	4.2E+07	0.4	5.8E+07	0.4	1.5E+08	0.4	1.2E+08	0.4
Pseudomonads	Important in nutrient cycling, assisting plants with phosphorus availability, and the biological control of plant pathogens.	1K - 1M CFU/gdw	0.5	4.9E+06	1.6	6.5E+06	0.9	2.0E+06	0.9	7.6E+06	1.1
N-Fixing Bacteria	Populations will proliferate as the available nitrogen in the compost decreases.	1K - 1M CFU/gdw	0.3	3.0E+04	0.8	1.4E+04	0.5	8.4E+03	0.5	1.8E+04	0.5
Total Species Diversity		High (>6.5) Low (<3)	4.9		5.9		4.6		4.3		6.2
Compost Maturity, percent (Phytotoxicity)		> 50 percent			Percent		Percent		Percent		Percent
					49.0		42.5		32.5		50.0
Stability, mg O2/Kg (Respiration Rate)		≤ 20 mg O_2/Kg (Horticultural)			mg O_2/Kg		mg O_2/Kg		mg O_2/Kg		mg O_2/Kg
		≤ 100 mg O_2/Kg (Field App)			32		23		25		28

Table 3. Capital Requirments and Costs, Annual Fixed, Annual Variable and Total Costs per Ton of Compost for Blend 3

						System 1			System 2		
Item	**Description**	**Unit**	**Useful Life**	**Cost Per Unit**	**Total Variable Costs**	**Quantity**	**Cost**	**Percent of Total**	**Quantity**	**Cost**	**Percent of Total**
Capital Requirments and Costs											
Land	Unimproved Land	Acre	--	2,050	0	2.48	5,091	22.2	6.42	13,165	22.2
	Compost Production Area	Acre	--			2.05			4.83		
	Materials Preperation and Storage Area	Acre	--			0.25			0.58		
	Retention Pond Area	Acre	--			0.18			0.43		
Improvements	Grading (5%) and Retention Pond	Acre	20	7,200	72		17,879	77.8		46,237	77.8
Subtotal							**22,970**	**100.0**		**59,402**	**100.0**
Buildings:											
Bagged Compost and Equipment Storage Building	Sq Ft (50' x 100')	Sq Ft	20	8.61	0.17				5,000	43,026	31.36
Screening and Bagging Facility	Sq Ft (50' x 150')	Sq Ft	20	8.61	0.22				7,500	64,539	47.04
Asphalt Pavement	Sq Ft (50' x 235')	Sq Ft	20	2.37	0.02				12,500	29,643	21.60
Subtotal							**0**	**0.0**		**137,208**	**100.00**
Machinery and Equipment:											
Tractor, 1 yd loader	85 HP	Each	20	42,250	13.23	1	42,250	35.6			
Tractor	140 HP	Each	20	91,900	19.65				1	91,900	15.7
Windrow Turner, PT 120	1,320 Cu Yd/Hr	Each	20	27,940	12.22	1	27,940	23.6			
Windrow Turner, PT 170	2,670 Cu Yd/Hr	Each	20	82,950	18.32				1	82,950	14.2
Front-End Loader, Skid Steer	60 HP	Each	10	20,000	12.36	1	20,000	16.9	1	20,000	3.4
Front-End Loader, 3 yd bucket	135 HP	Each	10	103,800	18.77				1	103,800	17.8
Truck, Dump Bed, Used	2 Ton	Each	10	11,400	19.05	1	11,400	9.6	1	11,400	2.0
Fork Lift	3000 lb lift	Each	10	9,852	3.77				1	9,852	1.7
Screen - Seperator	70 Cu Yd/Hr	Each	10	129,750	10.18 - 35.00				1	129,750	22.2
Bagging Machine	20 Bags per Minute	Each	10	72,000	2.63				1	72,000	12.3
Thermometers	Digital with 15 Second 36" Probe	Each	10	310	0.00	1	310	0.3	4	1,240	0.2
Volumetric CO2 Instrument	Digital with 36" Probe	Each	10	379	0.00	1	379	0.3	4	1,516	0.3
Water Pump	2 HP	Each	10	2,249	0.12	1	2,249	1.9	1	2,249	0.4
Windrow Cover	13 ft wide, various length	Sq Ft	10	0.21	0.00	66,823	14,089	11.9	172,810	36,434	6.2
Pallets	45" x 48"	Each	10	6.62	0.00				3,200	21,197	3.6
Subtotal							118,617	100.0		584,289	100.0
Total Capital Investment Costs							**141,586**			**780,898**	
Annual Fixed Costs											
	Land and Improvements						894	7.1		2,312	2.0
	Buildings						0	0.0		6,860	5.9
	Machinery and Equipment						7,399	58.6		44,230	38.3
	General Overhead						4,336	34.3		61,950	53.7
	Total Annual Fixed Costs						**12,629**	**100.0**		**115,353**	**100.0**
Annual Variable Costs											
	Materials						36,657	54.9		171,341	68.7
	Machinery and Equipment						18,872	28.3		49,533	19.9
	Labor						11,216	16.8		28,550	11.4
	Total Materials Cost						36,657	54.9		171,341	68.7
	All other Annual Variable Cost						30,088	45.1		78,083	31.3
	Total Annual Variable Cost						**66,745**	**100.0**		**249,424**	**100.0**
Summary of All Costs, Per Ton of Finished Compost											
	Capital Investment, per Ton of Final Product						31.19			43.00	
	Annual Fixed Cost, per Ton of Final Product						2.78	15.9		6.35	31.6
	Total Annual Variable Cost, per Ton of Finished Compost						14.70	84.1		13.73	68.4
	Materials Cost, per Ton of Finished Compost						8.07	46.2		9.44	47.0
	All other Annual Variable Cost, per Ton of Finished Compost						6.63	37.9		4.30	21.4
	Total Cost per Ton of Final Product						**17.48**	**100.0**		**20.09**	**100.0**

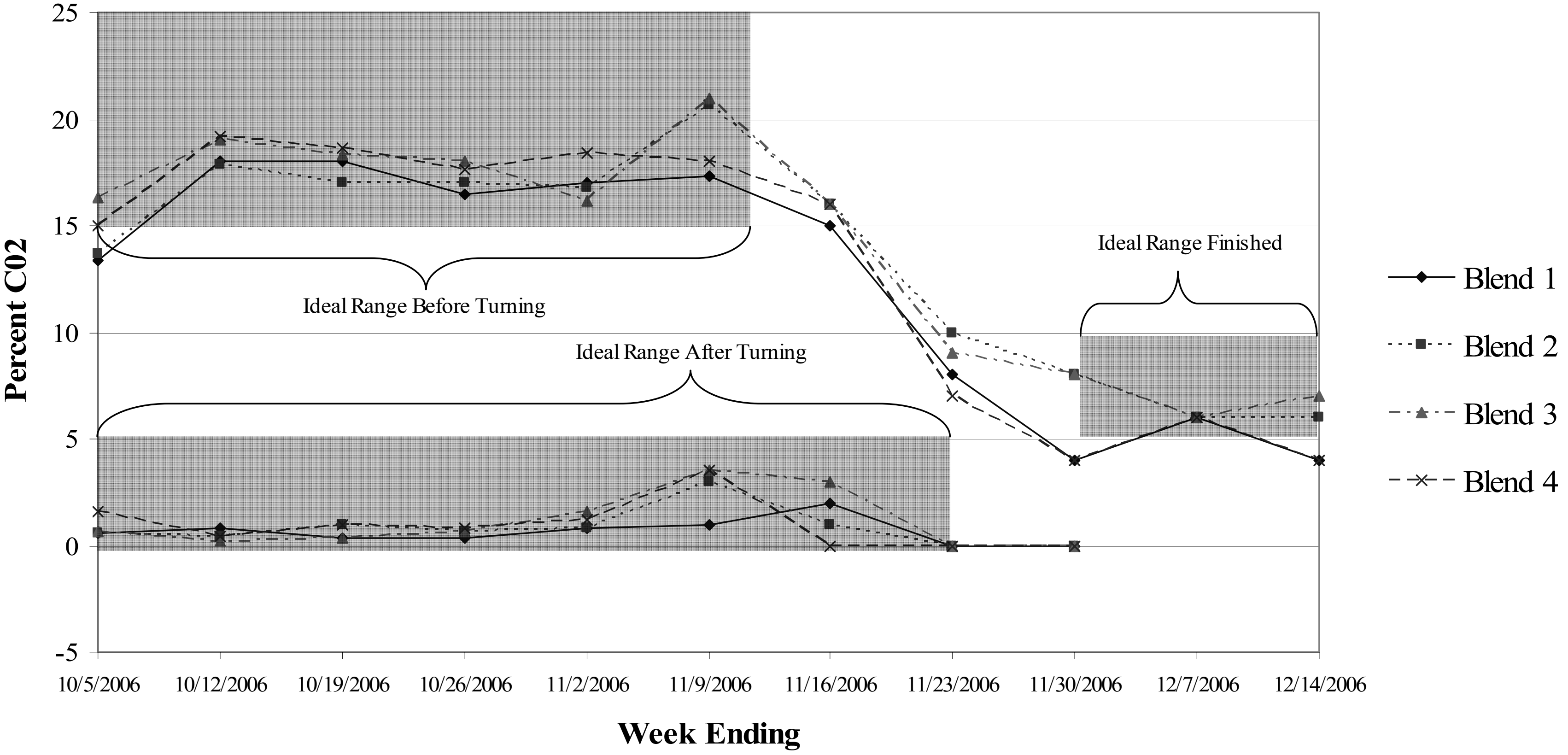
Note: Costs Before Interest and Tax where relevant

Figure 1. Mean of Weekly Temperatures (Prior to Turning) of Four Compost Blend



note: n=6 weeks 1 and 2; n=3 week 3 and 4; n=5 week 5; n=3 week 6; n=1 week 7, 8, 9, 10 and 11.

Figure 2. Mean of Weekly Percent CO_2 (Before and After Turning) of Four Compost Blends



note: n=6 weeks 1 and 2; n=3 week 3 and 4; n=5 week 5; n=3 week 6; n=1 week 7, 8, 9, 10 and 11. No turning weeks 10 and 11.