

Composting and Other Alternatives for Manure Processing

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Take Home Messages:

1. Intensive livestock operations generate large amounts of manure, which is generally not transported far from source. Over-application of manure can lead to soil, water and air quality problems.
 2. Composting is a means of reducing water content and mass of raw manure and potentially moving nutrients further away from source.
 3. A lot of different materials are called 'compost'. Composts are quite variable in terms of chemical properties.
 4. Open-air windrow composting of solid feedlot manure is fairly 'low-tech'. Other technologies include anaerobic digestion for production of biogas.
 5. Until now, cheap natural gas has precluded widespread adoption of anaerobic digestion in Canada.
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Introduction

Due to its high water content (up to 70% by weight), it is uneconomical to haul raw manure much further than about 15 km. Therefore, most manure is land applied close to source at high application rates. High manure application rates are not sustainable in the long-term and lead to environmental quality issues such as degradation of soil, water and air quality.

Recently, composting has gained increased attention as a means of reducing the environmental impact of feedlot manure. In southern Alberta, several companies are contract composting with local feedlots and compost is available for the agricultural market as well as the urban market and reclamation industry. Individual feedlot operations have also invested in composting mainly for use on their own farms.

Anaerobic digestion is another manure processing technology whereby methane gas is captured from manure and then used to generate electricity or bioenergy.

Composting

At the Lethbridge Research Centre, we have been conducting composting trials since 1997. Composting is an aerobic process in which manure organic matter is stabilized into a humus-like product called compost (Rynk, 1992). Raw manure is placed in long narrow open-air windrows and turned 5-7 times in a 3-month period and then allowed to cure for a further 3 months. We have reported on nutrient transformations (Larney et al., 2002a, 2002b, 2004c), physical changes (Larney et al., 2000) and greenhouse gas emissions during composting (Hao et al., 2001, 2004,

2005); use of compost in well site reclamation (Larney et al., 2003a, 2005a); elimination of viable weed seeds (Larney and Blackshaw, 2003), coliform bacteria (Larney et al., 2003c) and *Giardia* and *Cryptosporidium* during composting (Van Herk et al., 2004); carbon and organic matter relationships for compost (Larney et al., 2005b); a comparison of nutrients in fresh, stockpiled and composted manure (Larney et al., 2003b) and techniques for measuring gaseous emissions from composting manure (Sommer et al., 2004).

Recent work has aimed to characterize commercially available composts in southern Alberta. Larney et al. (2004c) tracked nutrient changes during composting at four commercial feedlots near Picture Butte, AB. Carbon (C) concentrations in the initial raw manure ranged from 23% to 35%. Carbon concentrations are highly influenced by the amount of bedding mixed with the manure and higher C levels point to more bedding material. As is normal, C concentrations dropped during composting as the microbes broke down C and emitted it as carbon dioxide. Carbon levels in the compost ranged from 14 to 21%. Nitrogen (N) levels in the raw manure ranged from 1.33% to 1.76% with an average of 1.56%. Nitrogen concentrations increased slightly during composting at three of the four feedlots and fell at one feedlot. The average value in compost was 1.67%. C:N ratio averaged 18.3 in the raw manure and fell to 10.6, which is typical of composting. During composting, 60-85% of the initial mass of water was lost, 22-50% of the initial mass of DM was lost and 43 to 74% of the initial total mass (combined water and dry matter) was lost.

Larney et al. (2004b) collected eight different composts from southern Alberta feedlots to get a 'snapshot' of C and N properties of commercially available material. Total N values showed a 2-fold difference ranging from only 1.03% to 2.16% total N. This means that twice as much of the former would have to be hauled in order to supply similar amounts of N to a soil or crop. C:N ratio is an index of compost maturity, decreasing during the composting process to values approaching 10:1. One compost still had a C:N ratio of 30:1 indicating that it was closer to raw manure than compost. The most mature compost had a C:N ratio of 9.6.

Soluble C probably consists largely of organic compounds that are easily decomposed by soil microbes. Consequently, organic amendments with high soluble C fractions may contribute less to long-term soil organic matter reserves, and may have a more immediate stimulatory effect on soil microbial populations. For the eight composts, there was about a 4-fold difference in soluble C, ranging from 5.1 to 21.9 g kg⁻¹. The proportion of C in soluble form ranged from 1% to 17%.

Soluble N is comprised of inorganic N (plant-available nitrate-N and ammonium-N) as well as the easily mineralized organic N fraction. Consequently, amendments with high soluble N concentrations have a higher short-term release of plant-available N than amendments with low soluble N. Values of the composts ranged from 4 to 20% of total N in soluble form.

Larney et al. (2004a) characterized P fractions in the same selection of commercial feedlot manure composts from southern Alberta. There was almost a 3-fold difference in total P content of the composts studied (0.4% to 1.12%). Composts (n=8) had between 73-89% of their total P in the inorganic form and 11-27% in the organic form. In contrast, manure (n = 2) had an average inorganic P content of 70% with 30% as organic P. This demonstrates that organic P breaks down during the composting process resulting in a final product with a higher proportion of inorganic P.

Helgason et al. (2005) reported that when a range of nine feedlot manure composts were added to soils and incubated for 168 d, there were substantial differences in the amount of C retained in

the soils (2-39% C added evolved as CO₂). Total C evolved during the incubation period could be predicted from the NH₄-N content and the NH₄-N/NO₃-N ratio of the composted manures (R² = 0.91-0.93). Estimation of the C retained in soils amended with compost as a function of simple chemical properties of the compost provides an important tool for evaluating the effectiveness of compost as a soil amendment, helping to calculate net retention of C.

Anaerobic Digestion

Anaerobic digestion (also known as fermentation) is widely used in Asia (especially China and India), less so in Europe and rarely in North America. Of the EU countries, anaerobic digestion is most common in Germany, Italy and Denmark. Two main barriers to the growth of anaerobic digestion technology in Canada are the belief that it is too costly and current manure management practices are sustainable (Green Matters, 2003).

At Vegreville, AB, Highland Feeders have installed an anaerobic digester (Li, 2003). Using a system known as the Integrated Manure Utilization System (IMUS), the digester is designed to overcome the challenges associated with high-solid manure typical of most outdoor feedlots in North America. It has the potential to produce renewable energy, bio-based fertilizers and reusable water (Fig. 1), while reducing greenhouse gas emissions and other environmental impacts. Biogas can be used to power co-generation units, which produce both heat and electricity. The heat can be used on the farm to heat buildings and/or the digester. The electricity can be used on site or sold to the power grid.

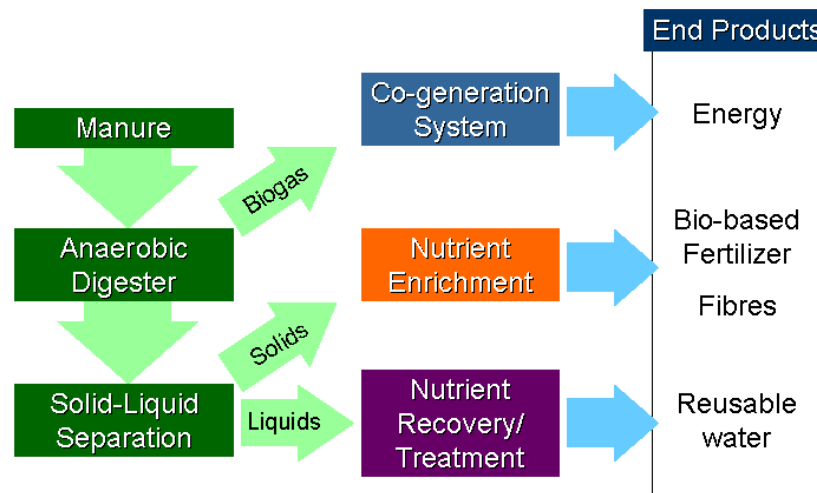


Figure 1. Schematic of Integrated Manure Utilization System (IMUS) technology in use at Highland Feeders, Vegreville, AB (Green Matters, 2003).

Highland Feeders, a family farm that produces grain and beef that has been in operation since 1947, adopted the IMUS technology in fall 2004 to produce 1 megawatt (MW) of electricity from the manure of 7,500 head of cattle. They eventually want to produce up to 3 MW of electricity, enough power to supply a town of over 5,000 people.

The IMUS technology integrates five main components: anaerobic digestion, biogas (mostly methane and carbon dioxide) utilization, wastewater treatment, nutrient recovery-enrichment and bio-based fertilizer production.

The process starts with manure which is diluted with water to improve its flow, then fed into the digester. Naturally occurring anaerobic bacteria (bacteria that don't need oxygen) break down the carbon in the manure and convert it to methane and carbon dioxide gas. The anaerobic degradation of organic matter is a sequential process in which several different groups of bacteria are involved. The methane is used to power a 1,500-hp engine, which cranks the generator producing electricity, which is sold to the Alberta power grid. The manure from six cows can generate enough gas to supply the electricity needs of one typical Alberta household for one year.

The whole process produces heat, which could be harnessed for a greenhouse, a fish hatchery, or an ethanol plant. It is hoped that the technology will be recognized as 'green energy' (energy generated from non-fossil fuels) and merit a premium. In Europe, governments have offered incentives for energy generated from manure (Burton and Turner, 2003).

Other Manure Processing Technologies

Treatment technologies for manure generally fall into two categories: those based on aeration or aerobic (e.g. composting) and those based on anaerobic treatment (e.g. anaerobic digestion). Other technologies for treating manure are presented by Burton and Turner (2003) and include:

- **Constructed Wetlands.** These can be used to treat liquid effluent e.g. wastewater from a dairy farm which has low organic matter and nutrient loadings.
- **Anaerobic Lagooning.** This is distinct from anaerobic digestion in that biogas production is not the primary purpose. Anaerobic lagoons offer low-cost, low-maintenance management along with storage capacity and at the same time allow some reduction of organic matter prior to land application. Recently, however, there has been a move to install covers on anaerobic lagoons to trap methane. Since methane is a serious greenhouse gas, these lagoons have to be regarded as having high environmental impact.
- **Separation.** Mechanical screening or a screw-press system can be used to separate solid and liquid fractions of hog and dairy slurries. Separation can also be done by sedimentation or centrifugation. The principle implies that separate solid and liquid fractions have reduced environmental risk compared to the non-separated raw product. Once separated, nutrients in the solid fraction are more stable and less mobile and the material can be land-applied or composted. The liquid fraction is more dilute and homogeneous and can also be land-applied.
- **Soil Filters.** The movement of manure through soil results in a high degree of purification as long as the treatment capacity of the soil is not exceeded. This is the result of a combination of physical separation processes, chemical reactions (e.g. phosphorus and heavy metals), biological and microbiological activity that breaks down and utilizes the manure nutrients. One example is the 'Solepur' process (Martinez, 1997) where pig slurry is applied to a field, which is drained to collect all leachate. The nitrate-rich drainage water is then treated in a denitrification reactor and the treated water is irrigated on adjacent fields.

Summary

In some areas of intensive livestock production, complete abatement of pollution from manure cannot be achieved by improved farming practices alone. Manure treatment technologies may have to be part of the solution in order to export nutrients from intensively farmed regions. Open-air windrow composting is a low-tech option. Specialized windrow turners, while better, are not required. Conventional farm equipment, e.g tractor and front-end loader may be used to mix material and aerate windrows. Anaerobic digestion is being mentioned more and more as a manure treatment technology in Canada. Pilot projects may demonstrate its feasibility under Alberta conditions.

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