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Manure to Energy Byproducts are Useful Nutrient Sources

Manure is a great fertilizer for nutrient-poor soils. However, when transport costs limit utilization, alternative uses such as energy production become viable. In most cases, manure-to-energy practices produce nutrient-rich byproducts that can be used as a soil amendment. While nitrogen (N) may be lost, other nutrients like phosphorus (P) and potassium (K) are often more concentrated in these byproducts.

Manure-to-energy practices include anaerobic digestion and thermal methods (pyrolysis, gasification). Composting and nutrient extraction also can alter manure and help concentrate nutrients for easier and less costly transport. All of these practices are discussed in *Manure as a Natural Resource* (EB-420).

Composting Can Lower Costs of Shipping Manure to Other Regions

Composting decreases manure mass and changes the nutrient content. As mass decreases, organic matter becomes CO_2. Nitrogen is often lost, but the concentration of P, K and micronutrients often increase (Table 1). However, P may not be readily available for use by plants.[1,2,3] The extent of Nitrogen loss depends on the bulking agent used (straw, woodchips, etc) and the type of animal manure (swine, poultry, dairy). With these variables, loss of N can range from 5-60%.[2]

Compost is a solid material with a consistency similar to manure, so it can be applied to fields with a spreader. A lab analyses of compost is necessary to determine nutrient content and land application rates.

Table 1: Nutrient contents of poultry litter by composting[1]

	N	P_2O_5	K_2O
	lb/ton		
Fresh	88	82	82
Composted	74	104	101

The results of research on composted manure as a nutrient source is mixed. Following composting, most of the remaining N is in stable organic compounds, but may not be immediately available for plants. Only 5% of organic N mineralizes for plant uptake in the first year.[4] The mineral N (NH_4, NO_3) content of compost represents the actual plant-available nitrogen (PAN) and is comparable to manure as a nutrient source.[4,5,6] Researchers found that P and micronutrients were plant-available

Table 2: Summary of the benefits and nutrient potential of alternative uses for manure				
Alternate Use	**Benefits**	**Nutrient Concentration**	**Land Application**	**Nutrient Potential**
Composting	Kills pathogens; reduces mass	N lost; P increases in concentration	Manure spreader	Limited NH_4; P and K still available
Anaerobic Digestion	Kills pathogens; energy production	NH_4 in liquid portion; P in solid fraction	Manure spreader; (dry) or liquid inject	Organic N already mineralized as NH_4
Thermal (Energy)	Kills pathogens; energy production	N lost; P increases in concentration	Manure spreader if pelletized	May immobilize soil N, P and K still available
Extraction	Kill pathogens; reduce nutrients	Lower manure N and/or P	Chemistry dependent	Extracted N/P similar to fertilizer

when tested with forages[6], although organic ligands may decrease micronutrient availability. Organic ligands that are not water soluble will bond with metals (Cu, Zn, etc) and reduce their plant availability.

Anaerobic Digestion Produces Energy, But Still Yields a Nutrient-rich Byproduct

Similar to composting, anaerobic digestion breaks down manure carbon, but converts it into an energy-rich gas (methane). The remaining byproduct, called digestate, can be either liquid or solid.

Compared to composting, the reactors used for digestion are closed to the atmosphere, so N becomes more concentrated rather than being lost (Table 3). In addition, the microbial breakdown of manures enhances the mineralization of N, increasing the amount of NH_4 from 10 to 33%.[7] A greater portion of the NH_4 is found in the liquid digestate, while P and organic carbon are concentrated in the solid portion. Due to the higher carbon but lower N content, the solid fraction may be a better soil conditioner than fertilizer. Some P as well as calcium (Ca), manganese (Mn), zinc (Zn) and copper (Cu) can be left behind in the reactors.[7]

The manure source is important for determining digestate properties. Liquid dairy digestate, for instance, may provide more P and K for alfalfa. Liquid broiler digestate, with its greater N content, may be better for grain crops.[8]

Table 3: Ammonium contents of anaerobic digestate from manures[8]	
	NH_4 (lb/ton dry)
Cattle (Fresh)	< 1
Digestate	4
Swine (Fresh)	<1
Digestate	4
Poultry (Fresh)	<1
Digestate	10

Since digestate can be either liquid, solid or a slurry, there are several land application methods. The liquid portion can be sprayed, banded or injected, while the solids can be field applied with a manure spreader. Due to the greater NH_4 content of the liquid digestate, injecting or incorporating it into the soil to prevent gaseous losses is recommended.[7]

For crop growth, the NH_4 content of digestate is most of the PAN, as the remaining organic N is in stable compounds. Mineralization of organic N is around 12%, but can vary. The availability of P is comparable to the original manure; however the greater pH can cause it to precipitate as the mineral struvite. The organic ligands present in the digestate may also complex with micronutrients and limit their short term availability.[7]

Digestate has performed well compared to manure and commercial fertilizers, but form is important. Pelletized digestate solids have released N slower than digestate or separated solids.[9]

Thermochemical Conversion Transforms Manure Using Heat and Can Alter Nutrient Contents and Availability

Temperature and oxygen content can vary with different thermal methods. These include torrefaction (low temperature), pyrolysis (300-800°C, no oxygen), gasification (>1000°C, some oxygen) and combustion (>2000°C, with oxygen).

Inputs can vary from peanut hulls to various animal manures.[10,11] This can lead to a range in byproduct characteristics, including pH, carbon and nutrient content.

At higher combustion temperatures, ash is produced, but *biochar* (charcoal) is a byproduct of pyrolysis at lower temperatures. For many manure types, N concentration increases up to 350°C, but decreases at 700°C.[7] The initial increased N concentration is due to the mass lost as carbon, but eventually higher temperatures also deplete N (Table 4).

Since P can't be lost as a gas, it rises in biochar concentration as temperatures increase (Table 4), similar to other metals (K, Ca, magnesium (Mg) and iron (Fe)).[10] While the concentration of these nutrients increases, plant availability may actually decrease.[12]

Land application of biochar as a nutrient source can be difficult if it is unevenly sized chunks or ground too fine. Pelletization of chars creates a more uniform product which is easier to apply with agricultural equipment.

Table 4: Nutrient content of fresh manures and their biochars at 700°C [11]

	N	P	K
	lb/ton (dry)		
Dairy	5	11	13
@700C	3	34	41
Poultry	7	28	13
@700C	4	62	128
Swine	8	49	22
@700C	5	118	51

During the charring process, NH_4 is typically lost as gas and the remaining organic N has lower mineralization rates, especially at higher production temperatures. Therefore, biochars are not necessarily good sources of N. When added to soils, depending on the properties of the biochar, soil N may also be immobilized.[13]

Biochars can provide P to crops, and have been successful at fertilizing ryegrass.[14, 15] When added to compost, biochars also performed well for vegetable production.[15] However, biochars may perform best as a soil conditioner, increasing pH, soil carbon and water use efficiency.[16, 17]

Testing is Necessary for Use as a Fertilizer

Although there is potential in all of the above byproducts in crop production, application will still have to follow nutrient management regulations. The nutrient contents must be tested in a lab prior to application to determine N and P availability for plant growth. The mineralization of N for each material will also have to be determined for both PAN as well as water quality concerns. Still, if energy production becomes a viable alternative for manure, these byproducts could help maintain manure's role as a nutrient source.

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