Livestock Manure Recycling in Korea by Anaerobic Digestion

Y. Joo and K. Lee
Rural Development Administration, Suweon, Korea

Abstract

The pollution problems of rural areas in Korea have increased in recent years mainly because of increased farm animal populations and inadequate, management of, manure. Farmers need to, manage animal manures properly to minimize the potential for environmental pollution.

One option involves the principle of anaerobic digestion, whereby animal manures are converted into high energy fuel (biogas) and into fertilizer and feed. The process also reduces the number of parasite eggs and pathogens, and helps to abate offensive odors in the slurry.

Introduction

Korea’s economic development plan has resulted in the rapid growth of industrialization and urbanization which, in turn, has brought new pollution problems.

Pollution from livestock manure was largely ignored until the early 1980s. However, population growth and the increased demand for meat and dairy products greatly expanded dairy and livestock production, which created serious pollution problems from improper handling of animal manures.

One cost-effective method of disposing of animal manure is by anaerobic digestion. The technology is relatively simple and produces a valuable fuel (biogas), a useful liquid fertilizer and an animal feed, and at the same time minimizes the pollution potential of a waste material.

This paper will discuss the anaerobic digestion technology and its benefits to livestock farms of Korea

Livestock Manure Production

The major contributors to environmental pollution in Korea in recent years are cattle and swine. As shown in Table 1, the number of cattle and swine in Korea has increased rapidly, from 3.3 million in 1981 to 6.9 million head in 1988. Accordingly, as the number of livestock increased, the amount of manure increased, with a production of almost 11 million Mg in 1988. This corresponded to a progressive increase in the biochemical oxygen demand (BOD) of the manure.

Today, the huge volume of manure produced by livestock farms has created a serious pollution problem which must be dealt with.

Table 1. Number of Cattle and Swine in Korea and Manure Production from 1981 to 1988.

Year	Number		Collectable Manure		BOD
	Cattle	Swine	Cattle	Swine	
	10^6		*10^4 Mg y^{-1}*		*10^4 Mg y^{-1}*
1981	1.5	1.8	493	158	48
1982	1.7	2.2	558	193	56
1983	2.2	3.6	723	315	78
1984	2.7	3.0	887	263	85
1985	2.9	2.9	953	254	89
1986	2.8	3.3	920	289	90
1987	2.4	4.3	788	377	86
1988	2.0	4.9	657	429	83

The high content of suspended solids, the high levels of nitrogen and phosphorus, the increased biological chemical oxygen demand, and chemical oxygen demand (COD), has resulted in the pollution of farmland, ground water, and the environment.

Principles of Anaerobic Digestion

Today, the production of organic waste materials from animal production and processing is unavoidable because of increased human population and consumer demand for dairy and meat products. Many of these wastes, however, can be converted into usable forms through anaerobic digestion. In this technology the organic materials can be decomposed anaerobically by microorganisms over a range of temperature and moisture conditions.

Studies of the microorganisms that are capable of this type of fermentation have been conducted for many years. However, there are two types of microorganisms that play a major role in anaerobic digestion. These are the facultative anaerobic bacteria that convert cellulose to glucose during the initial decomposition of the substrate, and obligate anaerobic bacteria, i. e., strict anaerobes, that are responsible for the final step in transforming the fermentation products into biogas and useful slurry fertilizer. The biogas generally consists to 30 to 40 percent carbon dioxide (CO_2) and 60 to 70 percent methane (CH_4).

Flexible Dome-Type Anaerobic Digester

The plant consists of a rectangular concrete digester and a flexible tarpaulin cover. The cover is installed over the digester by attaching the edges of the cover with a concrete channel surrounding the digester. The concrete channel is filled with water to provide a seal for preventing gas leakage (Figure 1).

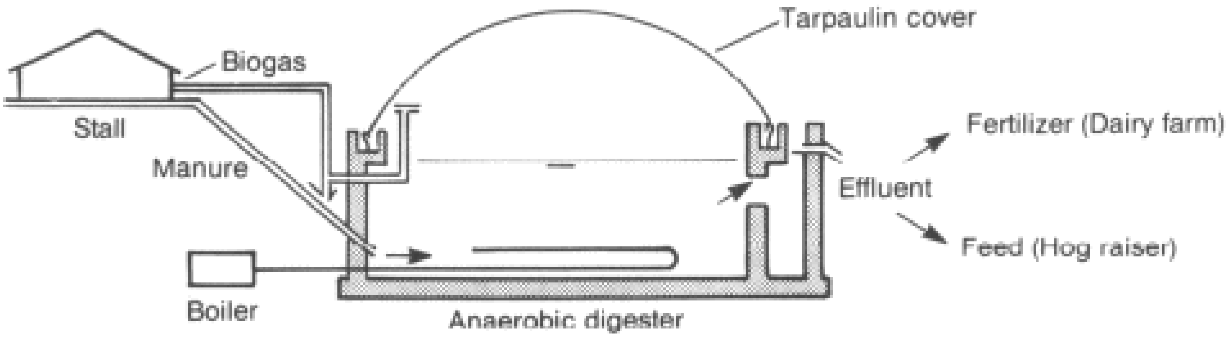

Figure 1. Schematic Diagram of Flexible Dome Type Digester.

During cold weather, the digester is heated by the circulation of hot water from a biogas-fired boiler. A polyethylene plastic sheet is installed over the digester to minimize heat loss.

The optimum scale of the plant for 40 head of cattle, or 80 head of swine, is 20 m^3. The installation cost for this plant is about $2,300 U.S.

Anaerobically Digested Slurry as a Fertilizer

The effluent slurry from the anaerobic digestion process has long been recognized as a valuable biofertilizer, because it can supply essential nutrients to crops and improve the physical and chemical properties of soils, making them more productive for crops. The percent composition of a rather typical slurry from anaerobic digestion of animal wastes is shown in Table 2. In addition to providing essential plant nutrients, the slurry is largely comprised of water which can also be utilized by crops.

A field experiment, in which slurry was applied at a rate of 12 Mg ha^{-1} for two years, showed that the content of soil organic matter was increased by 0.5 percent, bulk density declined by 10 percent, and total porosity increased by 4 percent (Table 3). There was also a substantial increase in soil phosphorus from the slurry.

The application of slurry to corn, sudangrass, and soybean gave yield increases of 29, 31, and 56 percent, respectively, compared with plots which received only chemical fertilizer (Table 4).

Table 2. Percent Composition of Slurry from Anaerobic Digestion.

Moisture %	Total Solids %	Volatile Solids %	Total Nitrogen %	P_2O_5 %	K_2O %	CaO %	MgO %
98.3	1.7	1.0	0.11	0.15	0.19	0.16	0.06

Table 3.Change in Soil Chemical and Physical Properties from Slurry Application.*

Treatment	Soil Depth *cm*	Bulk Density *g cm^{-3}*	Porosity *%*	P_2O_5 *ppm*	OM *%*
Control	0-5	1.19	55.2	71	1.4
	10-20	1.30	50.9	32	1.4
Slurry**	0-5	1.08	59.2	100	1.9
	10-20	1.24	53.3	40	2.0

* Soil: Clayey, Typic Haplucalf
** Slurry: Applied at a rate of 12 Mg ha^{-1}.

Table 4. Effect of Fermented Slurry and Chemical Fertilizer on Crop Yields.

Treatment	Corn	Sudangrass	Soybean
		kg ha^{-1}	
Chemical Fertilizer	10,500	4,800	158
Fermented Slurry	13,500	6,300	246

Anaerobically Digested Sludge as a Feed

Studies were conducted to determine the change in chemical composition of swine manure after anaerobic digestion, and whether the sludge from this process would be suitable as a feed supplement for swine. The sludge mixed feed (SMF) was formulated by mixing anaerobic fermentation sludge (AFS) and commercial assorted feed (CAF) in the ratio of one to four.

SMF was found to be lower in the ether extractable fraction and higher in crude fiber and ash than CAF. But there was no difference in crude protein for the two feed sources (Figure 2). The most notable difference was the higher content of threonine, Iysine, and methionine in SMF compared with CAF. However, there was no difference in the total amino acid content for either feed source (Figure 3).

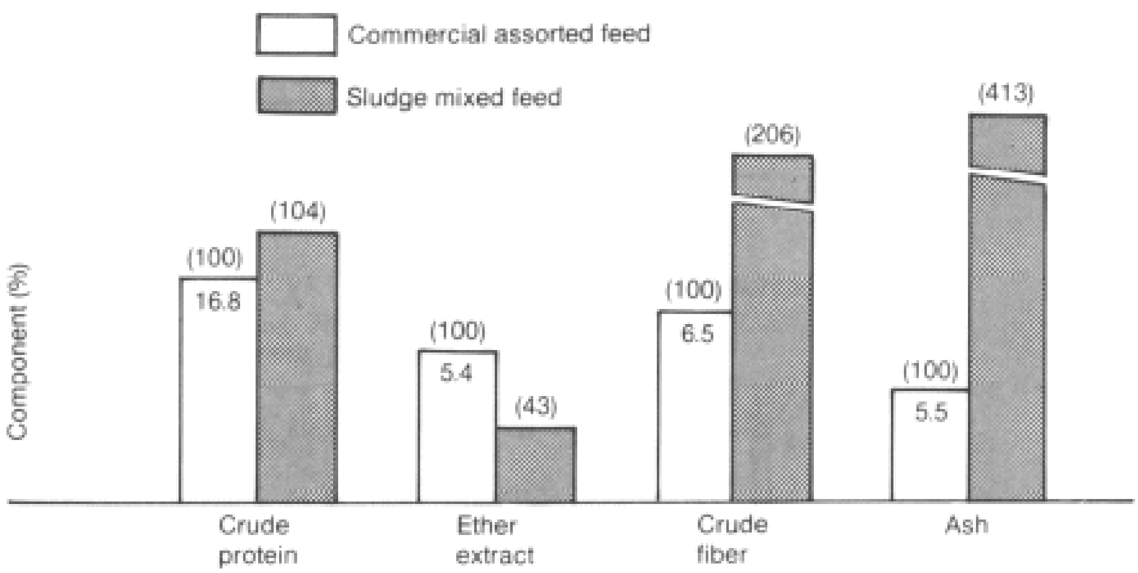

Figure 2. Nutrient Composition of Commercial Assorted Feed and Sludge Mixed Feed.

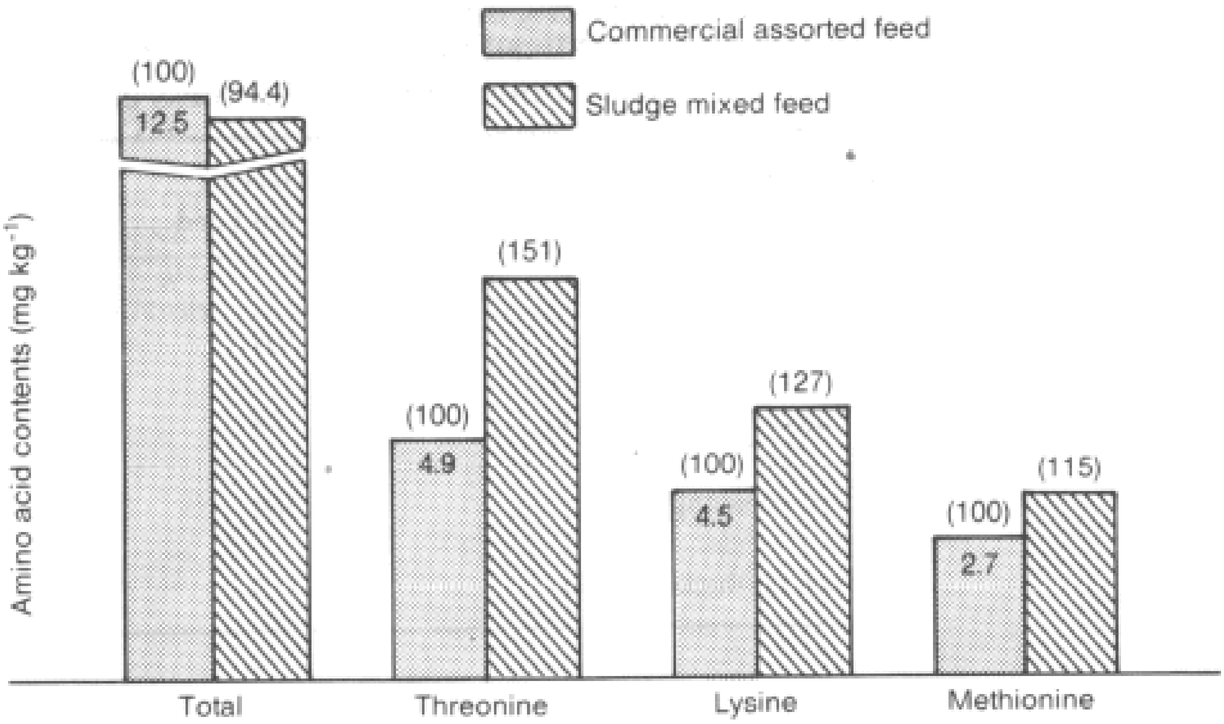

Figure 3. Essential Amino Acids Contained in Commercial Assorted Feed and Sludge Mixed Feed.

As shown in Table 5, the levels of riboflavin, pyridoxine, and cyanocobalamin were considerably higher in AFS than in swine manure. However, the thiamine content was lower for AFS than the manure. These results suggest that anaerobic fermentation of swine manure promoted the synthesis of substantial amounts of the B-complex vitamins, except for thiamine.

As shown in Table 6, the feeding of swine with SMF caused a slight depression in live weight of animals compared with CAF. However, the thickness of the fat layer of swine fed with SMF was 1 cm less than that of swine fed with CAF. Nevertheless, using SMF as a feed source for swine reduced the production cost by about 20 percent which is a significant economic benefit.

Table 5. Content of B-Complex Vitamins Found in Swine Manure, Commercial Assorted Feed (CAF), Sludge Mixed Feed (SMF), and Anaerobic Fermentation Sludge (AFS).

Materials	Thiamine (B_1)	Riboflavin (B_2)	Pyridoxine (B_6)	Cyanocobalamin (B_{12})
	mg kg-1	*mg kg-1*	*mg kg-1*	*mg kg-1*
Swine manure	2.21	6.49	1.13	0.31
CAF	2.46	3.06	1.68	0.12
SMF	2.35	4.34	1.89	0.40
AFS	1.39	9.33	2.56	0.76

Table 6. Effects of Commercial Assorted Feed and Sludge Mixed Feed on Live Weight, Feed Consumption and Fat Thickness of Swine.

Parameter	Commercial Assorted Feed	Sludge Mixed Feed
Live weight, kg	108	100
Gain of body weight, kg	88	80
Feed consumption, kg	304	280
Back fat thickness, cm	3.2	2.3

Solutions to Problems of Pollution

Developing anaerobic digestion technology is also an effective way of treating animal wastes and improving health standards in the rural areas. Swine manure subjected to anaerobic digestion for only one month can achieve the following reduction in pathogen levels: ascaris, 100 percent; trichuris, 96 percent; E. coli, 99.8 percent; and enterococcus, 96.8 percent (Table 7). Furthermore, it can abate offensive odors in the manure.

The purity of water is generally determined by the amount of organic matter that it contains in terms of BOD and COD Clean water should have a BOD level of less than 3 ppm. Anaerobic digestion can reduce BOD, COD, and volatile solids by 92, 68, and 78 percent, respectively (Table 8).

The hydraulic retention time of the substrate was greatly related to BOD reduction. The longer the substrate was held in the digester, the higher the BOD reduction.

Table 7. Kill Rate of Pathogens by Anaerobic Digestion.

Organisms	Influent	Effluent	Kill Rate %
Ascaris, EPG*	200	-	100
Trichuris, EPG	2500	100	96
E. Coli, CFU ml^{-1}**	445	77	99.8
Intestinal coccus, CFU ml^{-1}	128	40	96.8

* EPG: Eggs per gram of feces.

** CFU ml^{-1}: Colony forming units per ml.

Table 8. Average Concentrations and Percentage Reduction Pollutants from Anaerobic Digestion of Swine Manure.

Pollutant	Influent	1st Effluent	2nd Effluent
BOD, ppm	20,600	2,450 (88.1%)	1,650 (92.0%)
COD, ppm	65,400	38,100 (41.7%)	20,700 (68.4%)
VS*, %	6.92	3.5 (49.5%)	1.55 (77.7%)

* Volatile soils.

Conclusions

Currently, there are serious pollution problems in the rural areas of Korea that are associated with the dramatic increase in numbers of livestock, particularly cattle and swine, and inadequate methods of manure disposal.

A promising solution to this problem is the use of anaerobic digestion technology on farms which can convert animal manures into high energy fuel (biogas), and into useful fertilizer and livestock feed. This technology can also improve the health standards of rural people because it greatly reduces the levels of pathogens in the digested sludge and slurry, and abates offensive odors.