韓國의 家畜 排泄物 콤포스트化 作業 改善에 關한 硏究

A Study on the Improvement of Animal Waste Composting Operations in Korea

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摘 要

家畜排泄物의 콤포스트化 作業의 工學的인 局面은 畜産 經營의 畜産物 生産性, 에너지 保全, 公害防止와 糞尿處理의 勞力 節約에 緊密한 關係가 있다.

그러나 우리나라에 있어서 畜産業의 飼養 規模와 頭數는 每年 增加하고 있는 傾向인바 傳統的인 家畜 排泄物 處理 및 再利用 過程에서 發生되는 問題點에 對한 硏究 資料가 없고 特히 콤포스트化 作業이 原始的이므로 改善 確立이 切實히 要求되는 實情이다.

本硏究의 目的은 家畜 糞尿의 콤포스트化 作業 過程에서 工學的인 諸 問題點을 調査 分析하여 現狀을 評價하고 改善 方案을 摸索하기 위한 基本資料를 提供하고저 遂行하였다.

이에 관한 調査와 分析 結果를 要約하면 다음과 같다.

1. 畜産農家의 家畜 排泄物 處分 方法은 大部分이 自然乾燥, 堆積, 嫌氣的인 固形 또는 液狀 堆肥化에 의하여 實施되고 있었으며 家畜糞尿로 因한 公害는 深刻하다는 것을 알 수 있었다.

2. 好氣性 野積 콤포스트의 通氣作業은 트랙터에 附着되어진 前後 作動式 로우더가 바람직하다.

3. 農畜産 廢棄物의 콤포스트化 作業은 畜産農家를 中心으로 한 콤포스트 센타에서 全体 農家가 地方 增進과 汚染 防止를 하기 위해 參與하여 完全 共同 利用 体系에 따라 一貫性있게 遂行되어야 한다.

4. 好氣性 野積 콤포스트 作業은 다른 方法에 비하여 運營費가 적게 들어 零細的인 畜産業의 境遇에 가장 適當하고 公害를 防止함으로서 韓國 畜産農家의 콤포스트化 施設로 展望이 밝다고 判斷된다.

I. Introduction

In recent decades, the size of livestock farms in Korea has increased and pollution problems caused by animal waste are getting serious. Kim et al. (1982) pointed out that animal waste treatment and disposal systems are not provided with most dairy farms, therefore, pollution problems will be serious in the near future. Increased environmental regulations and rising fertilizer costs have made livestock waste management an important issue to Korean farmers.

Animal waste is an important source of energy. Utilization of livestock waste as fertilizer is more attractive for small scale farms compared to utilization as fuel (Harper and Seckler, 1980). Approximately 71% of the animal waste produced is spread on grassland for domestic use. The production of organic fertilizer from livestock waste through stock-

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piling, anaerobic composting, and natural drying has been practiced, but its importance was not recognized until the 1970's.

Disposal methods for rural waste are limited to three basic processes: land filling, composting, and incineration, Composting can be an effective method for reducing pollution and restoring valuable humus to the soil. Aerobic composting is based on the biodegradation of organic solids and liquids into a relatively stable end product which makes an excellent soil conditioner (Hong et al., 1983; Hortenstine and Rothwell. 1969). Aerobic thermophilic decomposition is an ideal method for composting solid waste without creating health hazards and has merit for a small scale farm.

For the most part however, anaerobic composting has been practiced by individual farmers and gardeners as a means of rural waste disposal and for returning plant nutrients to the soil. For solid livestock waste, composting is conducted either in windrows with aeration furnished by frequent turning (open compost system) or in bins using forced aeration (enclosed compost system). Composting liquid waste requires that the waste be heated to thermophilic temperatures in an aeration tank. However, the treatment cost is exorbitant, and is estimated at more than 100 times the cost of conventional composting of solid cattle manure (Sweeten. 1980).

Considerable research has been conducted in the United States on turned windrow, static piles, and mechanical composting systems. However, there has been little research effort for open windrow composting of solid rural wastes in Korea. Composting waste from livestock production is becoming an increasingly important concern. There is an active interest in developing procedures for an open windrow composting operation with subsequent use of the compost for crop production on large integrated farms. A practical and economical method of composting rural waste is urgently required. This study was undertaken for the following reasons: (1) to show that turned windrow compost systems are essential on a small scale farm, (2) to prove that compost is a valuable resource in Korea due to high fertilizer costs and loss of soil productivity, and (3) to show that composting rural waste uses little external energy.

The specific objectives of this study were: (1) present basic data on conventional animal waste composting by surveying farmers, (2) suggest improved methods for composting rural waste by windrow techniques, and (3) develop a reasonable composting system for soil conditioning and pollution abatement.

II. Survey Techniques

A. Survey Scope

This survey focused on the general aspects of Korean farmsteads and the profile of existing livestock waste composting methods. The survey information was analyzed and suggestions made for improving the traditional rural waste composting operation. This paper will discuss the current status and the prospect of developing a composting method for utilizing livestock waste as a renewable resource.

B. Survey Methods

Since there is no census of livestock farms, it is impossible to construct a random sample of livestock population. Therefore, a survey was conducted according to the following procedures: (1) a long questionnaire was sent to 92 regional livestock cooperatives throughout Korea, and (2) a field survey of 18 dairy farms around the Suncheon district was conducted by means of a brief questionnaire, direct measurements, photographs, and sketches. Forty-two farmers responded to the long questionnaire and their data was utilized in this study. The number of surveyed livestock farms classified by kind and herd size is presented in Table 1.

III. Field Data and Analysis

A. General Aspects of Livestock Farms

The trend in the size of the livestock industry

Table 1a. Number of surveyed farms based on herd size

Kind of cattle	No. of farms	Heads				
		Less than 10	10−19	20−29	30−35	36 or more
Dairy	30	1	9	7	10	3
Beef	20	5	2	3	6	4

Table 1b. Number of surveyed farms based on number of swine and poultry

Swine		Poultry	
Heads	No. of farms	Heads	No. of farms
Less than 20	8	Less than 1 thousand	1
20−49	6	1 −1.9	0
50−99	0	2 −4.9	1
100−499	3	5 −9.9	1
500 or more	3	10 thousand or more	1

and the size of animal herds are increasing annually in Korea. Livestock farms are widely scattered geographically and large quantities of waste cannot be accumulated in a central location. Half of the survey respondents had farms located near forest fields.

As shown in Table 3, dairy cattle account for 62% of breeding livestock. Based on the data in Table 1 one third of the surveyed farms average 30 to 35 dairy cows per livestock farm. The average livestock housing area is 0.09 ha and the cultivated grassland area for breeding livestock is 2.01 ha. Sixty-four percent of livestock farms manually used a vehicle and scoop to collect manure. Half the survey

Table 2. General aspects of surveyed farms

Items	Number	Percent
1) Kinds of raising livestock :		61.7
a) Dairy	26	26.7
b) Beef	11	7.1
c) Swine	3	4.8
d) Poultry	2	
2) Location of livestock farms :		
a) Around urban	8	19.0
b) Paddy field and upland	12	28.6
c) Grassland	2	4.8
d) Forest field	20	47.6
3) Livestock housing area :		
a) Below 0.01 ha	7	16.7
b) 0.01−0.19ha	31	73.8
c) 0.20−0.49ha	3	7.1
d) Over 0.5ha	1	2.4

4) Planted area for feeding livestock :		
a) Below 1.00 ha	16	38.1
b) 1.00−1.99 ha	5	11.9
c) 2.00−4.99 ha	10	23.8
d) Over 5.0 ha	11	26.2
5) Equipment for compost :		
a) Scoop and carter	27	64.3
b) Front-end loader	15	35.7
6) Disposal facilities of livestock wastes :		
a) Stack or compost yard	26	61.9
b) Slurry storage tank	12	28.6
c) Drying house	4	9.5
7) Major obstacles to managing livestock wastes :		
a) Handling cost	9	21.4
b) Compost yard and storing place	5	11.9
c) Heavy labour	21	50.0
d) Pollution	4	9.5
e) Water sources	3	7.2

Table 3. Number of laborers and required time per day managing the livestock wastes in a barn

Laborer	Percentage of laborer	Required hours/day	Average number of raising livestock	
			Cattle	Swine
1 − 2	33.0	2.0	26	41
3 − 4	31.3	2.4	56	56
5 − 7	21.4	3.2	64	177
8 or more	14.3	4.0	138	258

* Poultry number was excluded.

respondents claimed that the major obstacle for managing livestock waste was the heavy labor involved. The relationship between the number of laborers and the time required per day for managing livestock waste is shown in Table 2.

According to the respondents, most farmers had negative attitudes toward aerobic windrow composting on a small farm scale for the purpose of pollution abatement. The majority of farmers adopted natural drying, stockpiling, and anerobic composting for managing livestock wastes (Table 4), therefore, animal pollution problems were serious.

B. Current Status of Livestock Waste Composting

Figure 1 shows a classification of disposal methods for livestock waste based on separation techniques. One technique is non-separation of slurry and the other is separation of waste into liquids and solids. According to the respondents, liquid and solid separation of waste was achieved by manually operating a vehicle with a scoop in the stall barn. Non-separation methods involved spreading the slurry on the land or discharging the effluent to the river after anerobic digestion in a slurry tank for 10 days to 3 months.

A total of 42 farmers were surveyed to determine

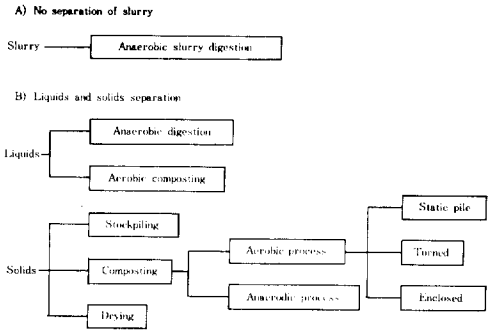

Fig. 1. General livestock wastes disposal process

Fig. 2. General view of the traditional composting site

their method for managing livestock waste. Livestock farmers who managed solid waste through stockpiling accounted for 62% of the respondents, as shown in Table 4. Stockpiling involved vehicles throwing the manure and bulking agent into a pile that was approximately 2-3 meters high and 5-7 meters wide. Farmers reported that they did not turn over the pile at regular intervals to ensure adequate aeration nor did they cover the composting material with a vinyl sheet to avoid the effects of climatic conditions. Approximately 64% of the farmers anerobically composted for 3 to 6 months. The end product was mostly for domestic use. Most farmers have a disregard for curing and drying the finished compost prior to storage or utilization.

Half the farmers have less than 10 m^2 for the purpose of composting in an installed area. A common type of manure gutter is used in a stall barn structure for managing dairy cattle manure. A stack or compost yard is the structure used most for the disposal of animal wastes. A general view of a conventional composting operation is shown in Figure 2.

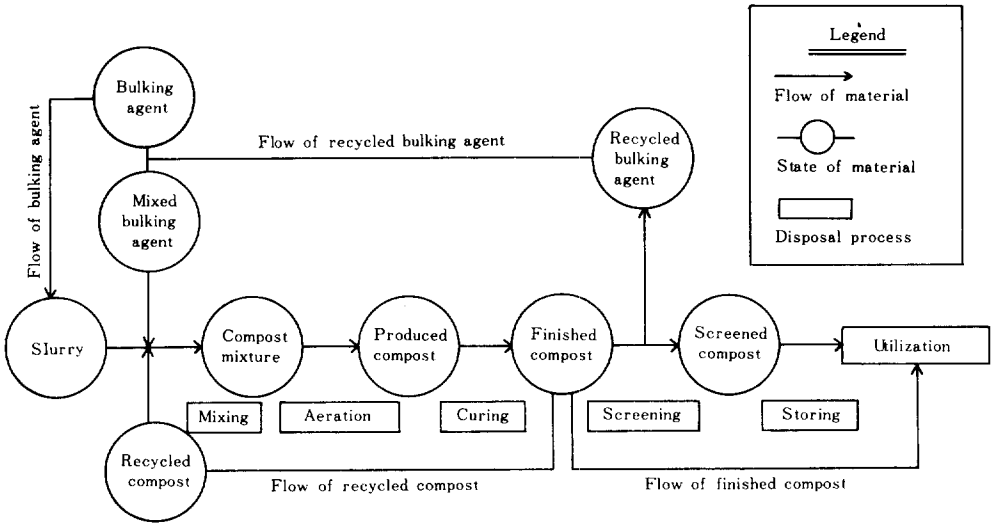

Fig. 3. Generic model of composting operation

Table 4 shows that 60% of farmers have no physical treatment for the prevention of foul odors and fly breeding. Therefore, conventional composting operations contribute to environmental pollution.

C. Improvement of Traditional Composting Methods

An arrangement for a composting process is shown in Figure 3. As indicated, the basic composting process unit operations are mixing, aeration, curing, drying, and screening. The first three unit operations are very important for efficient composting. However, there were almost no livestock farms following the basic unit operations in composting. These unit operations should be performed successively in an integrated cooperative operation system at a central location where all livestock farmer participate for the purpose of land improvement and pollution abatement. A recommended aerobic windrow composting center

Table 4. Analysis of composting questionnaire

Items	Number	Percent
1) Management method of livestock wastes :		61.9
a) Stockpiling	26	26.2
b) Anaerobic composting	11	0.0
c) Aerobic composting	0	11.9
d) Drying	5	
2) Kind of bulking material for solids composting :		
a) Rice hulls and straw	33	78.6
b) Sawdust	2	4.7
c) Others	7	16.7
3) Physical treatment for improvement of climatic conditions :		
a) No treatment	25	59.5
b) Turning compost materials	11	26.2
c) Insulating vinyl sheets etc.	4	9.5
d) Others	2	4.8
4) Required time for anaerobic composting :		
a) Less than 2 months	11	26.2
b) 3 to 6 months	27	64.3
c) 6 months or more	4	9.5
5) Application of compost :		
a) Domestic use	30	71.4
b) Sale to organic farmers	4	9.5
c) Exchange to regional farms	8	19.1
6) Working area for composting site :		
a) Less than $10m^2$	21	50.0
b) $11-50m^2$	9	21.4
c) $51-100m^2$	6	14.4
d) $101-200m^2$	3	7.1
e) $200m^2$ or more	3	7.1

for a dairy cattle housing system is presented in Figure 4.

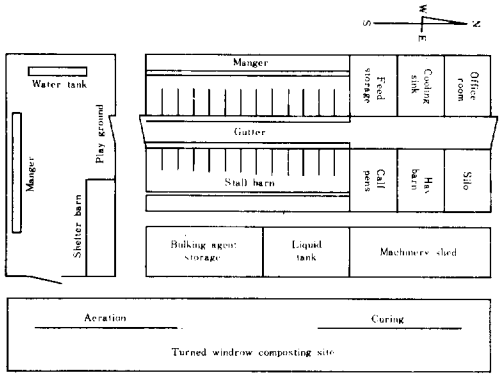

Fig. 4. Schematic plan of the desirable dairy housing for the turned windrow compost system in Korea

Improvements for a desirable open windrow composting operation are as follows:

Mixing - Slurry must be mixed with a bulking agent to facilitate handling the material as a semisolid and to adjust the moisture content for proper aeration prior to composting. The most suitable mix ratio of dairy manure to bulking agent for successful composting was two parts manure to one part bulking agent which produced an initial moisture content ranging from 55-65%. The slurry and bulking agent mixture is piled on the ground. The height of the pile should range from 1.5-1.8 meters. The sides of the compost pile should be inclined with the top rounded to shed water and preferably the pile should be covered with a vinyl sheet.

Aeration - The turning schedule varies according to climatic conditions. Generally, the windrow should be turned at 3-7 day intervals to maintain sufficient aeration for microbiological activity and to avoid a temperature decline to ambient levels. Equipment can be designed specially to accomplish aeration or general equipment, such as a front-end loader, can be used. Particle size of the bulking agent in the range of 1.5-5.0 cm is satisfactory for maintaining aerobic conditions. The bulk weight of the composting material should be in the range of 0.25-0.33 g/cm^3.

Curing - Curing further stabilizes the compost and dries it for screening. After 6 weeks of active composting, the compost is removed from the pile by a front-end loader, and stacked in windrows for curing and drying. The moisture content recommended for curing the compost is 50 percent for a higher degree of curing and ease in handling and screening.

Drying - Drying to a moisture content of 45-50% or less enables the compost to flow freely and be handled and screened without difficulty.

Screening - Screening separates the finished compost from the bulking agent which can be recycled. Unscreened compost can be used for land reclamation, but gardeners prefer screened material for top soil and fertilizer amendment. Storage space is dependent upon the amount of compost produced until utilization. Future Prospects for Composting Livestock Waste.

The agricultural population in 1981 was approximately 25.8 percent of the total population. The percentage of farm households under 1 ha was 66.3, in the range of 1-2 ha the percentage was 28.5, and farm households greater than 2 ha accounted for 5.2 percent (N.A.C.F., 1982)

In the past two decades economic development has encouraged agriculture to utilize chemical fertilizers and machinery. Fertilizer costs account for 11.9% of annual agriculture management expenditures. This economic growth has resulted in the imperfect management of the land causing decreased application of manure to the land while increasing the quantity of waste.

Estimates of livestock populations, waste quantities, and waste composition are shown in Table 5. The data shows that (1) livestock waste amounts to approximately 20.5×10^6 dry tons. (2) 88% of the total livestock wastes are produced by dairy cattle, and (3) the fertilizer value in livestock wastes amount to 22% of the annual cost of chemical fertilizer.

Table 5. Livestock population(N. A. C. F.), waste production, nutrients and energy in livestock wastes for 1981 based on waste composition(Tunney, 1980)

Determinations	Cattle	Pigs	Poultry	Total
Population in head	1506000	1832000	628400	
Tons per animal per year	12.0	1.2	0.36	
Waste in dry ton per year % dry matter	18072000 10	2198400 10	226224 20	20496624
Approx. waste composition				
kg per 10 ton, N	40	45	120	
〃 P	8	16	60	
〃 K	40	20	60	
Nutrients (x 10 dry ton), N	72.3	9.9	2.7	84.9(433)
〃 P	14.5	3.5	1.4	19.4(199)
〃 K	72.3	4.4	1.4	78.1(200)
Energy in Kcal	3614400	439680	45245	4099325

Note : 1) Animal waste energy, 5 Kcal / dry ton.
2) Figures in parentheses give the chemical fertilizer consumption per year.

Increased livestock production and rising fertilizer cost have made livestock waste management by composting an important issue to livestock farmers. The value of the finished compost may be relatively more valuable in Korea due to the limited quantities and the high cost of inorganic fertilizers. Compost is also a valuable amendment to soil that has lost its productivity due to intensive cultivation or erosion. Managing livestock waste by composting is a resource recycling approach to waste treatment that increases agricultural productivity and attains preservation of environmental quality.

The future for open windrow composting seems bright due to the concern over the disposal of rural waste in a manner that conserves plant nutrients and energy. Composting is a method of treatment that is less expensive than other methods, imposes little if any stress on the environment, and reclaims useful nutrients.

IV. Summary and Conclusions

A livestock waste composting operation has close connection with agricultural productivity, energy conservation, pollution abatement, and labor savings. In Korea, there is an annual upward trend in the size of the livestock industry and in the number of animal herds. However, there has been little research effort to improve the engineering aspects of conventional composting operations. The purpose of the survey was to determine the engineering problems of traditional composting operations, and recommend improvements for composting livestock wastes in Korea.

The results obtained can be summarized as follows:

1. Livestock farmers have traditionally adopted natural drying, stockpiling, and anerobic solid composting processes for managing livestock waste. The pollution problems from animal wastes are serious.

2. Composting should be performed by an integrated cooperative utilizing a system at a central location where all livestock farmers participate for the purpose of land improvement and pollution abatement.

3. Open windrow composting is an ideal method for composting solids waste because it is less expensive than other methods, does not create health hazards, and has merit for a small scale farm.

4. Utilizing a front-end loader for turned windrow

composting saves labor.

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