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OriginalArticle

Manufacturing and Utilization of Pelletized Livestock Manure Compost

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ABSTRACT

As of March 2011, there were about 3.3 million cattle, 7 million pigs, and 140 million poultry in Republic of Korea, producing about 46.5 million tons of animal manure. About 87% of the total produced waste is recycled to land as compost and liquid organic fertilizer. Compost made from livestock manure is an effective material for improving the physical and chemical condition of soil. However, there are few factors that limit the application of ordinary composted livestock manure. The major problem is that composted livestock manure usually has high moisture content, which deters to produce pelletized compost. This study was carried out to develop a new type of pelletizing system for high quality pelletized compost. Pilot scale pelletizing instrument system was developed, which can directly manufacture wet compost into pelletized compost without pre-drying of raw material. By using this pelletizing process, weight and volume of compost, and odor were reduced by 30%, respectively. Furthermore, nutrients of compost were not affected by pelletizing process. The High Heating Value (HHV) of pelletized compost with bedding material was 4,135 kcal/kg. As a result, pelletized compost could be used as good quality organic compost and a fuel for burner.

Keywords: Compost, Livestock,Manure, Pelletizing system.

INTRODUCTION

Livestock manure is an important resource for agriculture as it contains high level of nutrients and organic matter. The number of livestock industry in Korea has sharply increased over the past two decades, which results in greater awareness and concern for the proper storage, treatment, and utilization of livestock manure. The total amount of animal waste estimated in 2011 is about 46.5 million tons throughout the nation where 20.5 million tons (44% of total produced waste) originated from cattle. About 87% of the total produced animal waste is recycled to farmlands as compost and liquid organic fertilizer (Abedin and Kianmehr, 2012). The expansion of concentrated animal feeding operations has made it hard to reuse their manure because of the limited land area near the livestock farms, resulting in occasionally water, soil, and air pollution.

Livestock manure is a valuable resource in improving soil structure and increasing vegetative cover, thereby reducing surface runoff and erosion potential. Most of the livestock excretions were used as compost in Korea and the government encourages the farmers to use livestock excretions as a fertilizer. But the total amount of arable land for applying livestock manure compost is decreasing every year. For instance, the total arable land was 2,167,000 hectares in 1983, which has decreased gradually and reached to 1,729,982 hectares in 2012 (Ahn*et al.,* 2011). Another problem in utilizing the livestock manure compost is that rural population who are using compost made from livestock manure are becoming old. They are tending to use less compost because it is not so easy for the aged farmers to handle wet and heavy compost. Even livestock farms in some regions where the nitrogen content of the soil is low cannot find enough cropland on which to apply their compost. Groundwater has become polluted in these regions by nitrate due to heavy applications of composted livestock manure onto a limited area of cropland. Furthermore, the direct use of animal wastes acts health and environmental risks which should be treated accordingly. Stabilization deals with the decomposition of a waste substance to some extent where the hazards are limited and is normally reflected by decreasing microbial activity (AOAC, 1990). To reduce the environmental problems associated with the management of manure, stabilization is safer and suitable for application to soil (APHA, 2005).

There are two factors that limit the application of ordinary composted livestock manure. The first problem is that composted livestock manure usually has high moisture content and a high volume per unit of weight, which makes it difficult and costly to transport (Tesfay, 2014). However, Korean government forces livestock manure composting companies to keep the moisture content below 55% in their commercial compost. The second problem is that the quality of the compost and its nutrient content are not constant that limits the efficient use of compost. The pelletizing technology used for composted livestock manure could be an effective solution to both problems (Hara, 1998). A pelletizing machine could be the way to make composted livestock manure into pellets with advantages in transportation, handling and storage (Benito *et al.,* 2003; Bhattacharya *et al.,* 1989; Carr, 1995; Hansen *et al.,* 1995; Hara, 1998). If this is to be done without adding any other materials, it is important to control the moisture content of the compost. As a result, the objective of this study was to develop a new type of pelletizing system for high quality pelletized compost.

MATERIALS AND METHODS

Cow dung mixed with sawdust was used and cured under the aerobic condition. At the initial stage of curing, the moisture content of cow dung was adjusted around 65% by mixing with saw dust. The air was supplied from the bottom of the experimental compost pile through pipeline connected with mechanical blower (Agnew, 2003). The experimental compost pile was periodically mixed homogeneously by a skid loader. The variations of temperature and ammonia emission were investigated daily to get the information of curing state of the compost pile. When the temperature of the compost pile was near to ambient temperature and not varied any more, the compost was manufactured into pelletized compost by pelletizing instrument. Pig manure and poultry manure were also treated with the same manner (Farhadi, 2014). To pelletize the livestock manure compost, a new type pelletizing instrument was designed and manufactured in this study. The pelletizing instrument shown in Figure 1 was equipped with a screw type compressing part, input control unit and extruding part, etc.

Physico-chemical analysis of pelletized compost was conducted in accordance with standard methods (Jeong*et al.,* 2012; Peisker, 1994). To decide an optimum pelletizing instrument type, three types of pelletizing models were prepared. Screw extruding type pelletizing instrument, horizontal flat mill type pelletizing instrument and vertical ring mill type pelletizing instrument were selected as an early model of experimental instrument todecide ultimate experimental pelletizing instrument.

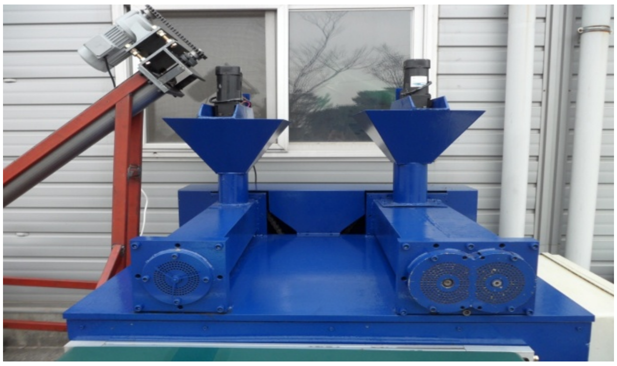


Figure1: Image of the experimental pelletizing instrument developed for this study

Figure 2 represents three types of early models used in this study for investigation. Pelletized livestock manure compost was dried by horizontal tunnel type drier (Figure 3).

External appearance of experimental drier | Inner space for drying pelletized compost

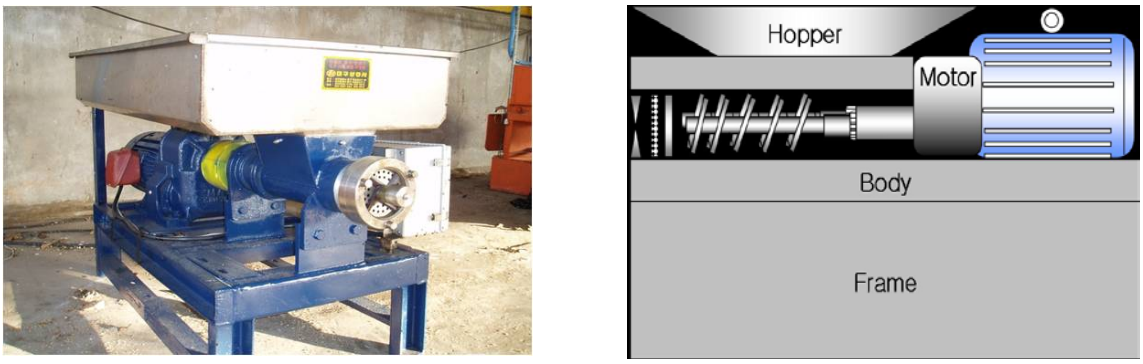
Figure2:Images of drier for pelletizing compost

RESULTS AND DISCUSSIONS

In Korea, livestock manure usually mixed with bulking agent such as sawdust, rice hulls and tiny woodchip; and then the mixed manure used to cure for dozens of days. During that period, the manure was generally turned over by the stirrer. Although after curing stage, the moisture content of cured livestock manure compost reached to 45-55%. This high moisture content of compost makes it difficult to produce pelletized compost. The moisture content ranges of livestock manure compost for this study is shown in Table 1.

Table 1: Moisture content ranges of livestock manure compost

parameters	Moisture content (%)
Cow manure compost	33-52
Pig manure compost	35-54
Poultry manure compost	38-51



Early model of screw type pelletizing instrument

Horizontal flat mill type pelletizing instrument

Vertical ring mill type pelletizing instrument

Figure3: Images of three types of early models used in this study for investigation

Livestock manure composts was manufactured in this study. To test the effect of pelletizing process, adding water or drying process were used to adjust the moisture content of composts as stuff for pelletizing when needed. The moisture content of compost for this study was adjusted at 33-54%. The distribution of particle size of cow manure compost for pelletizing was from above 2mm to less than 0.1mm. However, most particle size of the compost was between 0.85-0.425mm (Table 2).

Table 2: Distribution of particle size of cow manure compost

Dimension	Percentage	Dimension	Percentage	Dimension	Percentage
> 2.0mm	14.6	1.0-0.85mm	5.5	0.3-0212mm	7.8
2.0-1.7mm	5.4	0.85-0.6mm	14.6	0.212-0.18mm	2.7
1.7-1.4mm	4.0	0.6-0.425mm	14.1	0.18-0.1mm	4.0
1.4-1.0	13.9	0.425-0.3mm	9.3	< 0.1mm	4.1

It is evident that the compost has various contents of N, C, S, H and C/N according to the particle size of compost, which is shown in Table 3.

Table 3: Contents of organic matter according to particle size of compost

Dimension	N (%)	C (%)	S (%)	H (%)	C/N
> 2mm	1.329	20.95	0.447	9.294	24.08
2.0 - 1.7mm	0.636	18.11	0.396	9.742	29.46
1.7 - 1.4mm	0.582	18.22	0.401	9.688	31.30
1.4 - 1.0mm	0.589	18.55	0.402	9.548	31.41
1.0 - 0.85mm	0.569	19.15	0.388	9.349	34.22
0.6 - 0.425mm	0.645	19.56	0.394	9.312	30.35
0.425 - 0.3mm	0.942	23.03	0.431	5.320	24.45
< 0.1mm	1.538	27.90	0.700	6.323	18.14

According to Table 4, the optimum moisture content was different in types of pelletizing instrument. The optimum moisture content in screw type pelletizing instrument was 45-50% whereas it was 20-25% in mill type pelletizing instrument. The resistance of compression stress of pelletized compost was higher in mill type pelletizing instrument than screw type pelletizing instrument.

Table 4: Processing condition of compost according to pelletizing instrument type

Classification	Screw type pelletizing instrument	Mill type (flat, ring) pelletizing instrument
Optimum moisture content	about 45-50%	about 20-25%
Resistance of compression stress of pelletized compost	20 kg/cm	30 kg/cm
Solubility of pelletized compost	100% in 10h	90% in 10h

On the other hand, solubility of pelletized compost was higher in screw type pelletizing instrument. The moisture content of commercial compost in Korea is about 45-55% so the screw type pelletizing instrument was suitable for pelletizing of commercial compost. As a result, screw type of pelletizing instrument was selected as an ultimate experimental instrument for this study. Raw compost stuff and pelletized compost is shown in Figure 4.

Original compost Pelletized compost

Figure 4: Changes of compost shape by pelletizing process

Table 5 reveals the characteristics of cow manure mixed with sawdust, cow manure compost and pelletized cow manure compost. The content of NaCl, N, P, K, Cr, Cu, Ni, Cd, Pb and Zn was higher in pelletized cow manure compost than cow manure mixed with sawdust and cow manure compost.

Table 5: Characteristics of cow manure mixed with sawdust, cow manure compost and pelletized cow manure compost used in this study

Classification	NaCl	N	P	K	Cr	Cu	Ni	Cd	Pb	Zn
	mg/kg									
Cow manure mixed with sawdust	2,200	8148	3554	4957	1.17	28.82	4.82	0.53	3.68	89.43
Cow manure compost	2,200	11,304	4,636	5,134	1.99	39.77	5.29	0.62	8.48	130.94
Pelletized cow manure compost	2,900	10,996	5,948	5,563	2.44	42.68	7.50	0.76	6.81	147.84

The temperature of screw and ammonia emission was increased relatively to the revolution speed of screw of pelletizing instrument (Table 6).

Table 6: Emission of ammonia by revolution speed of screw of pelletizing instrument

Classification	10 RPM	15 RPM	20 RPM	30 RPM	50 RPM
Temperature of screw (℃)	25	27	32	27	45
Ammonia emission (mg/L)	10	14	20	22	27

It is shown in Table 7 that pellet productivity was highest at 50 RPM but the processing effect was lowest due to the revolution speed of the screw in pelletizing process. However, the nutrients contents of compost were not changed by pelletizing process (Table 8).

Table 7: Effect of pelletizing process by revolution speed of screw of pelletizing instrument

Classification	10 RPM	15 RPM	20 RPM	30 RPM	50 RPM
Amount of pellet produced (kg/min)	0.5	0.7	1.1	1.6	2.5
Processing effect (%)	100	100	95	90	81

Table 8: Changes of nutrients of compost by pelletizing

Classification	OM (%)	N (%)	P_20_5(%)
Swine manure compost	59.1	0.49	0.35
Pelletized swine manure compost	60.1	0.53	0.34

To investigate the pelletizing effect according to the thickness of compressing part, various thickness of compressing part were manufactured. Due to the thickness of compressing part of pelletizing instrument, the productivity and durability were different. The productivity of pellet was higher in thin compressing part than the thick compressing part. But the strengths of pellet were opposite. The compression part has two types of hole i.e. vertical and inclined. The edge of hole was cut and uncut as shown in Figure 5. As a result, pellet productivity was higher in inclined and cut type of compression part.

Figure 6 shows the change of moisture content of livestock manure and compost due to the elapse of drying time. The moisture content of livestock manure and compost was decreased when the drying time increased. According to drying of pelletized compost in dryer, temperature of compost pellet and ammonia emissions is shown in Figure 7. The temperature of compost pellet and ammonia emission was decreased when the time increased.

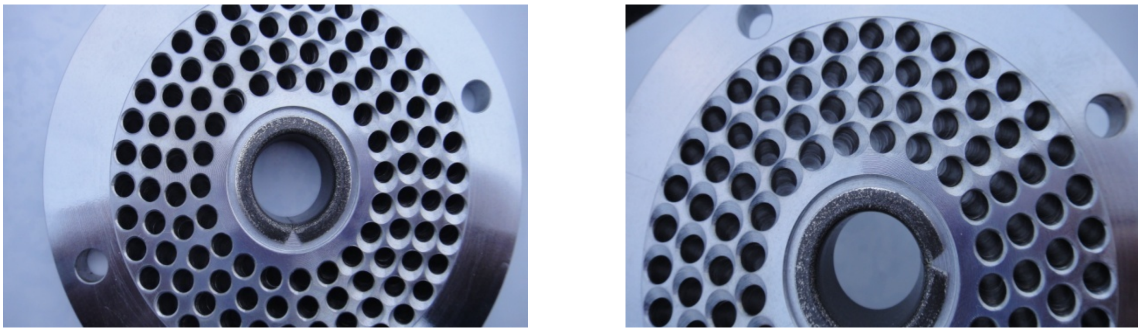


Figure5: Images of compressing part of pelletizing instrument

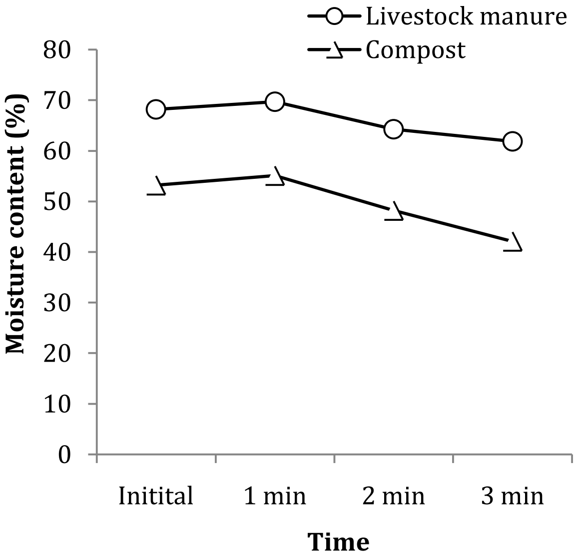


Figure6. Changes in moisture content by drying

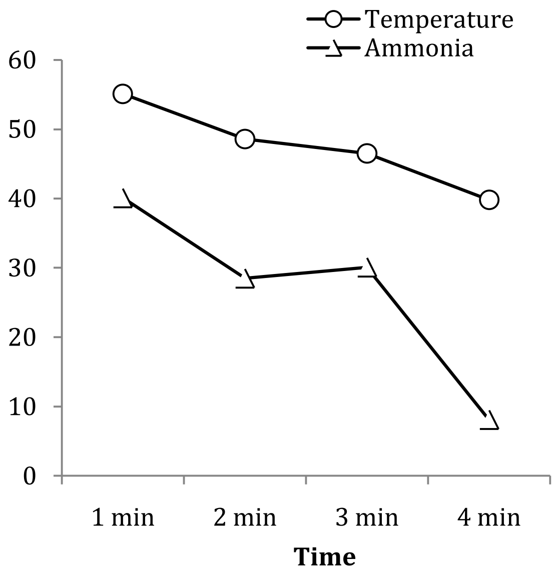


Figure7. Comparison of temperature of compost and ammonia emissions by drying

The comparisons of the emission of sulfur compounds by drying are shown in Table 9. Hydrogen sulfide (H_2S) and methyl mercaptan (MM) were not detected in compost. Furthermore, dimethyl sulfide (DMS) was not detected after 1 min of drying time. Table 10 shows the changes of high heating value of compost pelletized and raw compost. According to the elapse of drying time the high heating value was highest after 3 min. Changes of temperature and ammonia concentration of compost during pelletizing process is shown in Table 11. During pelletizing of pig and cow manure compost, temperatures and ammonia emission concentrations were increased due to the frictions and compressions of pelletizing process. Ammonia emission concentrations were increased because of the increased temperature originated from the mechanical performance of the pelletizing process.

Table 9: Comparison ofemissionof sulfur compoundsby drying

Classification	Sulfur compounds (ppb)		
	H_2S	MM	DMS
Compost	ND	ND	0.3582
Compost dried for 30 sec	ND	ND	1.9873
Compost dried for 1 min	ND	ND	ND
Compost dried for 2 min	ND	ND	ND

ND: not detected

Table 10:Changes of high heating value according to drying time

Classification	Initial	Compost dried for 1 min	Compost dried for 2 min	Compost dried for 3 min
	Kcal/kg			
Compost	3,113	3,002	3,022	3,256
Pelletized compost	2,866	3,185	3,044	3,032

Table 11:Changes of temperature and ammonia concentration of compost during pelletizing process

parameter	Pig manure compost		Cow manure compost	
	Raw compost	Pelletized compost	Raw compost	Pelletized compost
Temperature (℃)	27	47	25	51
NH_3 concentration (ppm)	25	45	12	39

Changes of volume of different pelletized composts with time have been depicted in Figure 8. The volume of the initial phase tended to decrease faster in case of oven-dried than air-dried pellet of pig and cow manure. After 30 days of drying, both oven and air-dried pellet reach to similar volume. In case of changes of weight, almost similar effects could be observed (Figure 9).

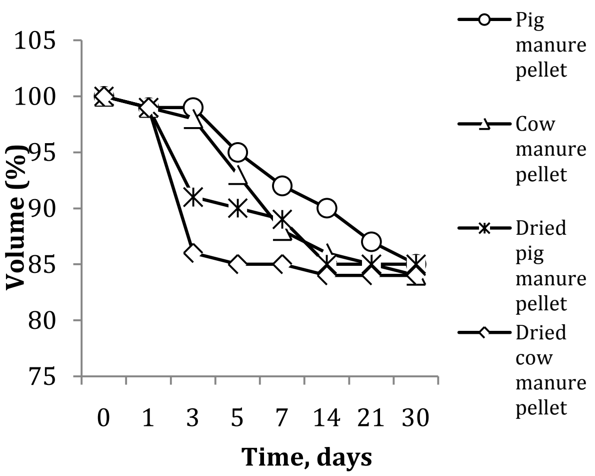


Figure8.Changes of volume of pelletized composts with time

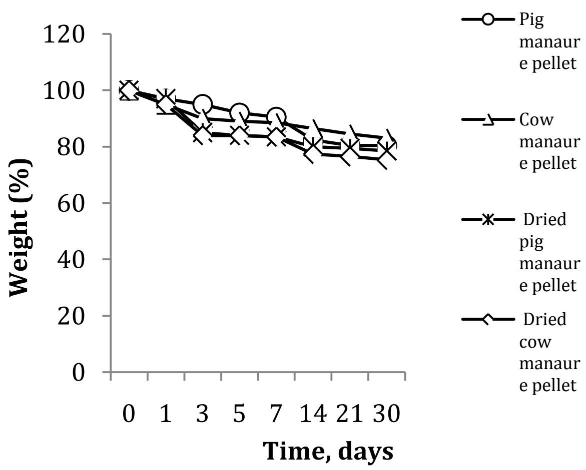


Figure9.Changes of weight of pelletized composts with time

CONCLUSIONS

Pelletizing instrument in pilot scale was developed in this study. By developing this new system, it can directly manufacture wet compost into pelletized compost without pre-drying process of raw material. The pelletizing efficacy was affected by revolutions per minute of screw and the type of extruder. When the screw revolves at low speed, the yield of pellet was decreased. However, the solidity of pellet was improved under the low speed condition. The weight and volume of pellet were decreased through drying process, which may take it easy to transport and spread to land as fertilizer. Therefore, the quality of pelletized livestock manure compost could be rich organic compost.

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