FERTILIZER PELLETS MADE FROM COMPOSTED LIVESTOCK MANURE

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ABSTRACT

Compost made from livestock manure is an effective material for improving the physical and chemical condition of soil. However, there are two factors that limit the application of ordinary composted livestock manure. The first problem is that composted livestock manure usually has a high moisture content and a high volume per unit of weight. As a result, it is difficult and costly to transport. The second problem is that the quality of the compost and its nutrient content are not constant. This also limits the efficient use of compost. The molding technology used for composted livestock manure is an effective solution to both problems. A pelleting machine is used to make composted livestock manure into pellets 5 mm in diameter. If this is to be done without adding any other materials, it is important to control the moisture content of the compost and the rate at which the compost is supplied to the die part of the pelleting machine. The dried pellets retain their form during storage and distribution, and have a volume only 60-90% of the raw compost. When the pellets are scattered, they generate only one-tenth or less of the dust generated by ordinary compost.

INTRODUCTION

Livestock manure is an important resource for agriculture, because it contains a high level of nutrients and organic matter. In Japan, the quantity of livestock manure has been increasing as farms have become larger and the number of livestock have grown. The total amount of livestock manure produced each year has now reached 97 million mt. The nitrogen content of this manure has been estimated at 7.6 million mt. If these animal wastes were to be recycled evenly over all Japan’s cropland, the load of nitrogen would be 140 kg/ha. However, actual recycling is uneven, and there are some regions where the nitrogen produced (250 kg/ha or more) exceeds the capacity of the soil to absorb it safely (Fig. 1).

On the other hand, many farmers who use compost made from livestock manure are becoming old, and are often part-time farmers. They are tending to use less compost because they lack the time and strength to apply it. Thus, even livestock farms in regions where the nitrogen content of the soil is low cannot find enough cropland on which to apply their compost. In these regions, groundwater has become polluted by nitrate because of heavy applications of composted livestock manure onto a limited area of cropland. Therefore, with these problems in mind, it is necessary to create an environmentally safe recycling system for composted livestock manure.

THE PROBLEM OF RECYCLING ANIMAL WASTES

In order to recycle animal wastes onto cropland without causing environmental pollution, we need to equalize the nitrogen load by transporting composted livestock manure from high-nitrogen areas to areas with a low nitrogen load. However, there are problems in both the quality and the handling of standard composted manure. The nutrient content of composted livestock manure and its fertilizer efficiency vary, according to the season, what the livestock are being fed, and other factors. The maturity of compost is difficult to define, and a
special machine is needed for spreading the compost. Finally, a large storage space is needed, and transport costs are high because the specific gravity of compost is low and the moisture content is usually high. Such factors limit the recycling of compost over wide areas, and discourage farmers from applying composted livestock manure.

Solutions to these problems must meet the following criteria if high-quality compost is to be produced:

1. The production of high-quality animal waste compost must meet the needs of arable farms by:
   * Guarantee the quality and also fertilizer efficiency;
   * Adjusting the nutrient content of the compost produced according to the nutrient requirements of the crop.

2. The production of animal waste compost must be made suitable for distribution over a wide area by:
   * Decreasing the volume of the compost;
   * Decreasing the moisture content of the compost.

3. Crop producers need to be able to apply compost easily. For this, they need a formulation suited to mechanized application.

4. Extension manuals are needed to show crop producers how to use the compost as fertilizer.

The solution is to mold compost into a granular or pellet form. This Bulletin introduces the basic technology that produces cylindrical pellets 5 mm in diameter, using a molding machine. It also discusses the fertilizer efficiency of the pellets, and how they are applied to arable land.

**THE MOLDING MACHINE**

There are two kinds of molding machine available on the market which shape composted livestock manure into pellets. One kind is the diskpelleter (dry molding method), and the other is the extruder type (wet molding method) (Fig. 2).

Molding machines which are of the diskpelleter type are of three kinds: the roller disk die type, the roller ring die type, and the double die type. Each type has a basic structure of a disk with many holes and a roller or two disks. The compost is fed between the disks and/or roller, and as the disk and/or roller turns, the compost is forced into the holes, producing the pellets. When compost with a lot of hard foreign bodies is used in this machine, damage to the dies and roller is severe, and demands the frequent replacement of the machine’s components. However, the machine does not become blocked, because it able to grind down the compost even if sawdust and rice straw are mixed into it. This method is suitable for raw material which has a comparatively low moisture content of 20-30%.

Molding machines of the extruder type have a barrel into which the raw material is forced by a screw. The material is then compressed into the die installed at the end of the machine, producing the pellet. This method has several benefits. The temperature can be controlled by adjusting the pressure, while it is easy to make pellets of various
shapes by simply replacing the die. However, one disadvantage is that such a machine is easily blocked by foreign bodies such as long fibers and small stones.

**PROCESSING OF COMPOST PELLETS**

Compost pellets should be a high-grade product with several desirable qualities. For example, they should be durable enough to maintain their shape when being transported to distant areas. They should be easily spread by machine. The quality and the nutrient content should be constant. They should not deteriorate during prolonged storage.

The quality of the pellet from each machine is determined by the character of the compost which is the raw material, by the size of the apertures and the power of the molding machine, and by moisture management during the molding process. The production of compost pellets should be seen as a system which begins with the making of the compost, and which ends with the packaged pellets (Fig. 3). It is necessary to understand how to manage the compost as a raw material, in order to produce the best possible pellets.

**Operating condition of the machine**

With both extruders and disk pelleters, the operating condition of the machine influences the processing speed, and thus the strength of the pellet. For the extruder types of machine, the speed of the screw which mixes the compost, and also the speed of the extrusion screw, are very important. For the disk pellet type of machine, the speed with which the compost is fed to the die is important.

Which operating conditions are best depends on the ingredients and maturity of the compost, and the kind of machine.

The characteristics of the compost used as raw material must first be determined, in order to see which type of machine is most suitable for processing the compost (Fig. 4).

**Moisture content of the compost**

For both types of machine, the moisture content of the compost is the most important factor. This greatly influences the strength and the processing speed of the pellet. The best moisture content is about 40% for an extruder, and about 20-25% for a disk pellet. The fluidity of compost falls with a lower moisture content, and friction resistance increases as the compost passes through the hole of the die. Therefore, the strength of the pellets increases, although damage to the extrusion screw may also increase, as may the power load.

The influence of the moisture content of the raw compost in the extruder is shown in Fig. 4. Although the strength of pellets increases, processing performance falls by 30-5-% if the moisture content of the compost is only 5% higher or lower than its optimal level.

The dies of both types of molding machine tend to block if the moisture content is too low. A electric drill is needed to remove the blocked compost, requiring considerable time for repairs. It
Fig. 3. Flow chart of pellet production

Fig. 4. Effect of a change in sawdust percentage or moisture content of compost on strength and processing speed of pellets. The machine is an extruder type.
is therefore important to make sure before processing that the moisture content of the compost is optimum.

**Characteristics of compost suitable for molding**

The characteristics of a compost which is a suitable raw material for making pellets are shown in Table 1. If compost with low fluidity and a high percentage of a bulking agent such as sawdust is used, the processing speed is slow and the pellets lack strength. It is preferable to use compost with 40% or less sawdust mixed in. This gives a pellet which has enough strength to maintain its form when it is stored and distributed.

It is also important to use compost which does not contain metal debris or stones. These damage the machines, and repairs and replacements add to the production cost. Pellets must be suitable for use as a high-quality organic fertilizer, because the pellets are expensive to produce. The compost used should have a stable and assured nutrient content without seasonal fluctuations, and contain a high level of nutrients.

If a livestock farm wants to produce molded compost pellets, it must consider both the method to be used, and whether the compost used as the raw material is suitable for pelletization. Compost of swine and poultry manure fermented in an enclosed vertical reactor usually includes few other materials, so it can produce high-quality pellets. The compost made by this method is immature because the period of composting is too short, although it has high fertilizer efficiency. Additional materials do not need to be added to the compost, and nitrogen losses are less than in other methods of compost production. An enclosed vertical reactor is the most suitable method of composting the raw material, because to some extent it can control the moisture content of the compost.

**Quality control for the pellets**

It is important to prevent a deterioration in quality if pellets are stored for a long time. Compost pellets become moldy if they are packed and stored without drying (Table 1). Therefore, it is necessary to reduce the moisture content of the pellets to 20% or less. Compost pellets generate more mold on the surface than ordinary compost, even if the compost has the same moisture content. If the compost used to make the pellets is immature, deterioration is very noticeable. During the summer, it is necessary to reduce the moisture content of the pellets to 15% or less if cost permits, because deterioration by condensation is caused even at a 20% moisture content.

**BENEFITS OF COMPOST PELLETS**

**Suitable form for long-distance transport**

Transforming livestock wastes into pellets makes them much more suitable for long-distance transport. The volume of pellets 5 mm in diameter is only 50 - 80% of the original compost (Fig. 5). Compost with a high percentage of sawdust makes pellets which are lower in volume. By compressing the pellets and reducing their volume, the pellets become better suited to transport over long distances, so that recycling becomes extremely cost effective. Another benefit is that the compactness of the pellet requires less storage space during the off season.

**Suitable for mechanized spreading**

The compost pellets are comparatively uniform in size and quality. They can be applied by various kinds of machinery which crop farms already possess. They are strong enough to be applied by machine without disintegrating. When compost pellets made from swine and poultry manure are used as an organic fertilizer, it is important to distribute them evenly. Machines such as the “Broadcaster” or the “Limesower” make precision application possible. If farmers use a “Blendcaster”, it is possible to apply chemical fertilizer at the same time.

A further benefit is that the pellets can be spread near residential areas, because they do not generate dust.

**Fertilizer efficiency of compost pellets**

The fertilizer efficiency of pelletized compost does not differ essentially from that of the compost which was used as the raw material. Therefore, the pellets can be applied to crops according to the present standard application rates for organic fertilizer. The pellets expand and their shape becomes distorted when they are soaked in water.

However, the effect on crops of the pellet is rather different than that of ordinary compost. The shape of the pellet persists in upland soils for a comparatively long time (Fig. 6). The breakdown of pellets in upland soils is slower than that of...
Table 1. Effect of moisture content on the quality of the surface of compost pellets

<table>
<thead>
<tr>
<th>Shape</th>
<th>Moisture content (%)</th>
<th>Surface quality&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Microorganism count</th>
<th>CO&lt;sub&gt;2&lt;/sub&gt; emission (3 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Storage days</td>
<td>Bacteria</td>
<td>Actinomycetes</td>
</tr>
<tr>
<td></td>
<td>0  3  7  10  14  21  28</td>
<td></td>
<td>0  28</td>
<td>0  28</td>
</tr>
</tbody>
</table>
| Pellets   | 40                   | — Δ © ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● •<ref>https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6257041/</ref>
ordinary compost. Therefore, even if the compost used as the raw material is immature, the negative effect on the plant caused by the rapid decomposition of easily decomposable organic matter is limited.

Compost pellets are leached of their bases and release nitrate nitrogen several weeks later than ordinary compost. Therefore, an anaerobic state is maintained inside the pellets, so that nitrification increases (Fig. 7). These characteristics are more pronounced in larger pellets, in pellets containing a smaller amount of bulking agents and other additional materials, and in pellets made from immature compost. On the other hand, molding into pellets has no effect on the mineralization rate over time of nitrogen (Fig. 9). The fertilizer efficiency of compost pellets seems to vary according to the nature of the compost used as the raw material and the soil conditions. It is also necessary to examine the technology used for applying the pellets to crops, if we are to understand fully the effect of pellets on crops and soils.

![Table 2. Physical properties of compost pellets](image)

<table>
<thead>
<tr>
<th>Shape</th>
<th>% sawdust</th>
<th>Compressibility¹ (%)</th>
<th>Cutting strength (kg)</th>
<th>Collapsibility² (%)</th>
<th>Bulk density (kg/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost used as raw material</td>
<td>nil</td>
<td>100</td>
<td>—</td>
<td>—</td>
<td>0.39</td>
</tr>
<tr>
<td>Pellet (ø 5 mm)</td>
<td>nil</td>
<td>78</td>
<td>4.30</td>
<td>98.1</td>
<td>0.50</td>
</tr>
<tr>
<td>Pellet (ø 10 mm)</td>
<td>nil</td>
<td>87</td>
<td>8.20</td>
<td>98.2</td>
<td>0.48</td>
</tr>
<tr>
<td>Pellet (ø 5 mm)</td>
<td>28%</td>
<td>69</td>
<td>3.85</td>
<td>97.6</td>
<td>0.43</td>
</tr>
</tbody>
</table>

¹ Compressibility: Volume of pellet (1 m² dry matter)/Volume of raw material compost (1 m² dry matter)
² Collapsibility: Conforms to the strength measurement used for pelleted livestock feed. Pieces 4 mm or less in diameter were assumed to be from pellets which had disintegrated. Criteria value is 95% or more.

Fig. 5. Improved ease of distribution after molding into pellets
We examined the effect of applied pellets on vegetable production. The pellets were made from composted swine manure only, without any additional materials. We substituted 100%, 50%, and 25% of the nitrogen contained in the normal basal dressing of chemical fertilizer with the composted pellets. The uptake of nitrogen and yield were investigated. The results are shown in Table 3.

For winter crops of cabbage (Brassica oleracea L.), the yields from the plot where pellets were applied were lower than plots where compound fertilizer was used. This may have been because the pellets contain less of the nitric form of nitrogen. The temperature of the soil over the winter cropping season is low, which limits nitrification.

This problem can be solved by applying the pellets earlier, or by applying more of them. However, increasing the application rate to meet the nitrogen demand might cause an imbalance of other nutrients, not only for this crop, but for the following crop. Therefore, it is considered that pellets are not suitable as a basal dressing for vegetables grown in autumn and winter. On the other hand, pellets are well suited to vegetables grown in spring and summer. For spring and summer crops, pellets can substitute for about 50% of the nitrogen applied as
Fig. 7. Effect of molding on leaching of nutrients from compost. The compost, including that used for the pellets, was made from swine manure only, without any additional materials.

Fig. 8. Effect of molding on growth inhibition
Control: Composted swine manure compost without any additional materials
Table 4. Effect of cropping index of vegetables when pellets are used to substitute for a basal dressing of nitrogen

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cropping period</th>
<th>Rate of nitrogen substitution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Spinach (Spring/Summer)</td>
<td>May - July</td>
<td>102</td>
</tr>
<tr>
<td>Spinach</td>
<td>June - July</td>
<td>111</td>
</tr>
<tr>
<td>Pak Choi (Summer)</td>
<td>July - Aug.</td>
<td>95</td>
</tr>
<tr>
<td>Marrow</td>
<td>June - Oct.</td>
<td>115</td>
</tr>
<tr>
<td><strong>Summer crop average</strong></td>
<td></td>
<td>106</td>
</tr>
<tr>
<td>Cabbage (Winter)</td>
<td>Oct. - Feb.</td>
<td>85</td>
</tr>
<tr>
<td>Spinach</td>
<td>Oct. - Nov.</td>
<td>90</td>
</tr>
<tr>
<td><strong>Winter crop average</strong></td>
<td></td>
<td>88</td>
</tr>
</tbody>
</table>
a basal dressing.

CONCLUSIONS

The following two points are important in promoting the recycling of livestock wastes the use of compost. The first point is to establish technology for producing high-quality compost from livestock farms which meets the demands of crop cultivators. The second is to establish a method of fertilizing crops which takes into account the needs of the environment. Molding composted livestock wastes into pellets can solve both problems, and seems to be a promising technology. However, before it can come into widespread use, there are still problems remaining to be solved. The most important is to reduce the manufacturing cost.

REFERENCES


DISCUSSION

In the discussion after this paper presentation, several people pointed out that making compost into pellets is still a relatively new technology in Japan, and asked if the technology could be transferred to other countries. In particular, there was concern about the production costs. Dr. Hara explained that the production costs depend on the volume of the output, but are generally 3-15 Yen (US$ 0.03) per kilogram at the farm level. The throughput each day for an average on-farm operation is around 1.5 mt of compost, which makes about one mt of pellets. An operation of this kind in Japan could expect to have the following production costs.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>123 Yen</td>
</tr>
<tr>
<td>Repairs and maintenance</td>
<td>50 Yen</td>
</tr>
<tr>
<td>Electricity</td>
<td>12 Yen</td>
</tr>
<tr>
<td>Labor</td>
<td>60 Yen</td>
</tr>
<tr>
<td>Cost of bagging</td>
<td>30 Yen</td>
</tr>
</tbody>
</table>

Total = 302 Yen (c. US$3.00) per 20-kilogram bag

However, these production costs are lower if the production output is higher. Dr. Hara pointed out that the molding of compost into pellets is now widespread in Japan, especially in the Kyushu area, which is a high-nitrogen area.

Dr. Hara was asked why there is less leaching of nitrate and more leaching of ammonium from upland soils if pellets are applied. He replied that there is usually rapid leaching from compost in upland soils. However with pellets, nitrification is slower because the pellets retain their shape and are anaerobic inside. He was also asked whether pellets involved any increase in the total leaching of total nitrogen content, compared to ordinary compost. He replied that pellets and ordinary compost are much the same in this respect.