PELLETIZING WASTE COMPOST AND FLY ASH MIXTURE TO PRODUCE FERTILIZING MATERIAL

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Abstract – The basic idea in this study is to develop a method to convert compost waste into pellets with the addition of fly ash. The pellets are to be used as soil conditioners suitable for plant production. The article introduces a method of how to make compost waste and fly ash easier to process and distribute, to enhance their soil improving and fertilization properties, and to improve the preconditions for their exploitation in general. The effect of raw material characteristics on pelletization and plant production are shown. According to the results, the pellets withstood handling to a certain extent, and their size and form varied significantly but remained distributable. The product granules can be used as a fertilizer or soil conditioner, as such, for certain garden plants, or for private home gardens where the pellet-provided nutrient amounts can be quite sufficient. However, the fly ash component of the granules should be clean enough or cleaned from heavy metals by, for example, electrostatic precipitation.

1. INTRODUCTION

Lately the possibilities to recycle wood ash have been studied extensively. Wood ash contains most of the elements (P, K, Ca, Mg, B, etc.) needed for plant nutrition and gives a good increment to tree growth, especially on drained, nitrogen-rich peat soil [1]. Wood ash is also known to be an effective substance in reducing soil acidity.

Fly ash originates from wood and peat bio fuel of heating energy and power plants. The amount of fly ash is particularly large when using a circulating or bubbling fluidized-bed boiler. That kind of fly ash is very dusty and contains no N, and the amounts of C are minor. Therefore, addition of nitrogen and granulation of fly ash is necessary to make the ash applicable to fertilization and to improve its handling and storage characteristics. Granulation should be carried out using a layering method like tumble agglomeration where also chemical stabilization of fly ash is possible [2]. This process includes hydration of ash that induces a series of chemical reactions, some leading to the formation of less soluble secondary minerals like $Ca(OH)_2$ (portlandite) [3]. This granulation method produces porous agglomerates which may easily be exposed to air, leading to transformation of hydroxide to $CaCO_3$ (calcite). In this case, the stability and the mechanical characteristics of ash particles may thus depend on the dissolution and precipitation of calcite, which processes are expected to depend on pH and CO_2 partial pressure [4].

The aim of the pretreatment is to make ash applicable to fertilization and to improve its handling characteristics. The applicability of ash can be made safer and more extensive by decreasing the content of heavy metals like cadmium by fractionating the fly ash in the power plant [5]. According to the results [5], electrostatic precipitation is an adequate method in the fractionation of fly ash to be used as a fertilizer or soil conditioner.

Granulation has many advantages, e.g. significant reduction of dust problems. Granulated material spreads easier than untreated ash. The transport and spreading costs are also smaller. The granulation process improves the metering and dosing characteristics, and permits the particle size and composition of the ash product to be controlled [6]. For example, adding dolomite insures sufficient levels of the important nutrients Ca and Mg in the granules [7]. And, finally, the granulation improves the product appeal and sales value.

In layering granulation, the liquid and solid phases are brought into intimate contact to develop binding forces and to cause agglomeration. The most common wetting phase is water or an aqueous solution with capillary binding forces developing in the wet agglomerates. Also other liquids and binding mechanisms may be used, resulting in adhesion and cohesion forces, solid bridges through chemical reactions and attraction forces between solid particles. In most cases the granules, i.e., the green pellets are formed by mixing the materials in an inclined disc, cone or drum [8, 9].

In Finland, municipal waste compost is mainly used for landscaping and landfill purposes. The erratic quality of compost, diverse composting degree, unsatisfactory hygienic quality and the scarcity of soluble nutrients have restricted its usage in more reasonable objects. The spreading and handling characteristics of compost and its nutrient content may be improved by mixing wood or peat ash with matured compost and by granulating the mixture by a layering method.

According to the authors’ experience, fresh moist compost can be pelletized for example with a balling disc or sieve machine where a screen plate moves linearly back and forth. When the moisture is high enough, the granules become stronger after drying and withstand normal handling.

The aim of this study was to determine the possibilities to improve the handling and fertilization characteristics, and the refining value of compost through addition of fly ash and granulation.

2. MATERIALS AND METHODS

Municipal biowaste compost and biowaste sewage sludge compost were both mixed with cleaned and uncleaned fly ash and used in granulation tests. Fly ash, as fresh as possible, was stored in a dry place. Cleaned fly ash was produced in an energy plant by collecting the fly ash from the first collector chamber of the electrostatic precipitator. The unclean fly ash was taken from the ash silo where the entire fly ash is conveyed. The compost materials were screened before pelletizing with a 20-mm sieve and the coarse material was rejected.

Laboratory granulation tests were done with a balling disc pelletizer (Fig. 1) and the pilot granulation test with the same kind of equipment but larger in diameter (Table 1).

Figure 1. Laboratory disc pelletizer, diameter 0.4 m [10].

Table 1. Main dimensions and operational parameters of the laboratory and pilot discs.

	Unit	Laboratory disc	Pilot disc
Diameter	m	0.40	1.0
Rim height	m	0.09	0.3
Inclination	°	55	58
Critical rotation speed	rpm	60	40
Theoretical capacity	t/h	0.16	1.00

The optimal agglomeration conditions were determined through laboratory tests before carrying out the pilot tests. Especially the amount of binder water was critical and dependent on the moisture content of the compost. The amount of water was estimated visually so that after proper mixing time the water, ash and compost were well blended and the mixture looked moist but not wet. The aim was to have a moisture content near or at capillary state in the agglomerates. At the capillary state the wet agglomerates are known to be strongest. Mixing was stopped when the whole mixture still looked granular. The small grains of the moist mixture may be assumed to be the seeds of the pellets. The amount of each granule type produced for the plant experiment was about 425 kg. In the granule product the fraction of ash was 30 % and of compost 70 %.

The wet granules were placed on a hall floor as a 10-cm layer and were allowed to dry. The bed was mixed every once in a while during the few weeks' drying period.

The dry solid content of granules and the compressive strength were determined with a Shimadzu Penetrometer (Fig. 2). The strength value was measured as N of pressure applied. Because of the different sizes of pellets, a standard minimum value is difficult to assign. According to the literature, smaller pellets, 1 mm in size, may have a compressive strength of 5 N and still be strong enough for handling and spreading. Larger pellets should have higher compressive strengths.

The nutrient and heavy metal contents of the granules were determined at the laboratory of MTT Jokioinen. The samples were taken during the granulation and immediately before the granules were spread in the field. The soluble contents of heavy metals were analysed by AAAc-EDTA leaching.

Figure 2. Compressive strength equipment, Shimadzu Penetrometer.

The granules were applied to the field at the establishment of an annual grass experiment (Italian rye-grass, *Lolium multiflorum*) in May 2003 in order to determine the fertilizing effect of compost-ash granules vs. genuine compost material. The amount of compost applied was determined according to the total nitrogen application, with the same application as t/ha fresh matter adapted for the granules produced from the corresponding compost. The granules and composts were sampled at the time of application and spread manually, the surface layer was cultivated and grass was sown. In addition to granules and compost, no additional fertilization was applied in 2003. Mineral fertilization treatment with 250 kg N/ha was applied as an optimum control. Italian rye-grass was cut three times with yield determinations and the plant material was analysed for nutrients and trace elements.

3. RESULTS AND DISCUSSION

The results show that all cadmium concentrations are well below the recommended limit value, 3 mg/kg (Fig. 3). Also the other heavy metals were clearly below the national limit values.

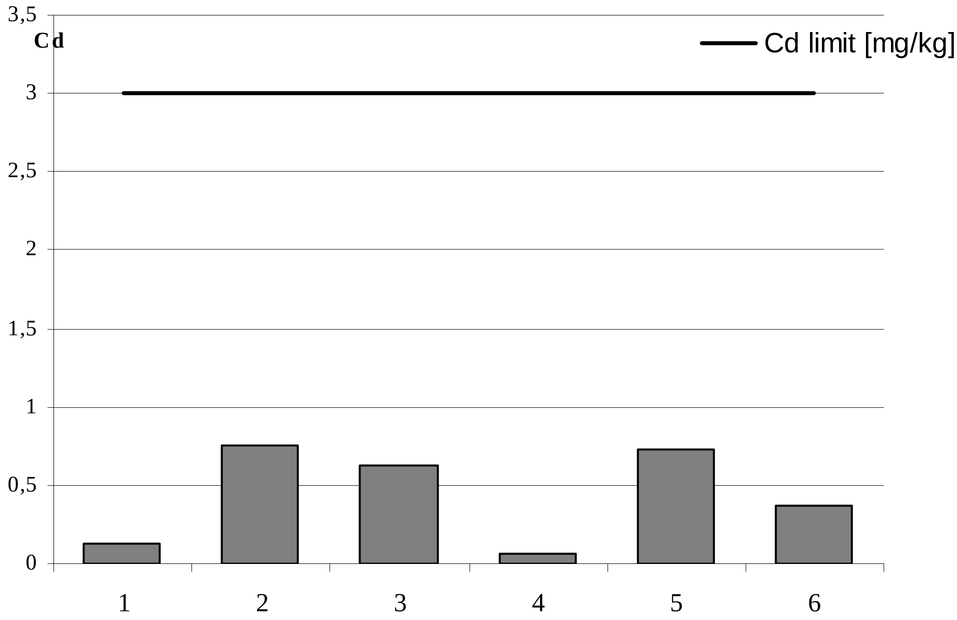

Figure 3. Average cadmium content (AAAc-EDTA leaching, mg/l) of compost and granule samples: 1 biowaste sewage sludge compost, 4 biowaste compost, and of granule samples: 2 biowaste sewage sludge compost + ash, 3 biowaste sewage sludge compost + cleaned ash, 5 biowaste compost + ash, 6 biowaste + cleaned ash.

The use of clean and uncleaned fly ash did not affect the granulation and mechanical granule characteristics. Meanwhile, the diverse quality of the compost clearly affected the granulation. As a result of the heterogeneous structure of the compost, the size and form of the granules varied significantly. If equal sized granules are aimed at, the compost should be refined before granulation.

The compressive strength of the product granules was normally in the range of 2 - 3 N, but all the values were below 6 N. Thereby the granules withstood handling to a certain extent. The quite coarse fibre components of the compost in the granules are probably the reason for the fairly low compressive strength values. Because of the elasticity of the fibre components, the granules withstood handling quite well. In summary, the granulation improved the handling and spreading characteristics, and reduced dust formation.

The total N content decreased with ash addition compared to genuine compost, whereas for the biowaste compost and the corresponding granules the ash addition increased the total P content (Table 2). The soluble contents of P, K, Mg and Ca (AAAc-EDTA extraction) were generally remarkably increased with ash additions, except for the biowaste compost granules (2 and 3 in Table 2). The soluble content of N (as a sum of ammonium and nitrate) decreased with ash additions. The contents of Cd and Pb increased clearly in the granules with ash additions compared to genuine compost materials. The soluble nutrient and both total and soluble trace element contents of the granules were generally decreased with cleaned ash compared to addition of uncleaned ash for granules (Table 2).

Table 2. Chemical characteristics of composts and granules at the time of establishment of the field plant experiment in 2003.

	1	**2**	**3**	**4**	**5**	**6**
P total (g/kg dm)	2.8	6.2	4.6	19.9	15.0	13.0
P soluble (mg/l soil)	150	90	201	48	81	99
N total (% air dry)	1.81	0.92	1.06	2.39	1.15	1.23
N soluble (mg/l soil)	291	108	182	1452	1091	1134
K soluble (mg/l soil)	1993	2898	2307	1255	2183	1728
Mg soluble (mg/l soil)	701	1412	1132	416	1258	1133
Ca soluble (g/l soil)	3.27	19.4	10.9	3.41	20.0	15.2
Cd total (mg/kg dm)	0.2	2.2	0.7	0.5	2.1	1.4
Cd soluble (mg/l soil)	0.1	0.7	0.4	0.1	0.8	0.6
Pb total (mg/kg dm)	9	40	23	14	37	40
Pb soluble (mg/l soil)	3.8	9.5	7.4	3.0	8.5	9.6

1 biowaste compost, 2 biowaste compost + uncleaned ash granules, 3 biowaste compost + cleaned ash granules,
4 biowaste sewage sludge compost, 5 biowaste sewage sludge compost + uncleaned ash granules,
6 biowaste sewage sludge compost + cleaned ash granules.

The amount of total N applied with compost ash granules was clearly lower than with the genuine compost material (Table 3), whereas the granules with cleaned ash provided a slightly higher amount of N compared to granules with uncleaned ash. From the genuine compost materials, the amount of trace elements applied increased with ash addition in granules. On the other hand, the granules with cleaned ash (materials 3 and 6 in Table 3) caused generally a lower Cd and Pb load on soil.

The yield results showed a clear deficiency of soluble N in annual rye-grass production (Figure 4). The major part of total N in compost materials is in organic form, with only a small portion of total N in soluble form (ammonium and nitrate). The organic N is slowly released from the organic waste materials. The applied plant was highly efficient in utilizing nutrients and it had also a long period of growth. Thus, some modest plants with lower nutrient requirements could be suitable objects for compost granule fertilizers. There should be efficient formulation and optimization of application rates as well as chemical analysis in order to overcome the general nutrient limitations of waste materials [11].

Table 3. The applied amounts of compost and granules, and the total amounts of nitrogen, Cd and Pb applied at the experiment in 2003.

	1	**2**	**3**	**4**	**5**	**6**
Applied amount (t/ha fm)	23	23	23	16	16	16
Total N applied (kg/ha)	280	150	170	267	137	154
Cd (g/ha)	3	35	12	6	25	18
Pb (g/ha)	140	650	373	154	442	502

1 biowaste compost, 2 biowaste compost + uncleaned ash granules, 3 biowaste compost + cleaned ash granules,
4 biowaste sewage sludge compost, 5 biowaste sewage sludge compost + uncleaned ash granules,
6 biowaste sewage sludge compost + cleaned ash granules.

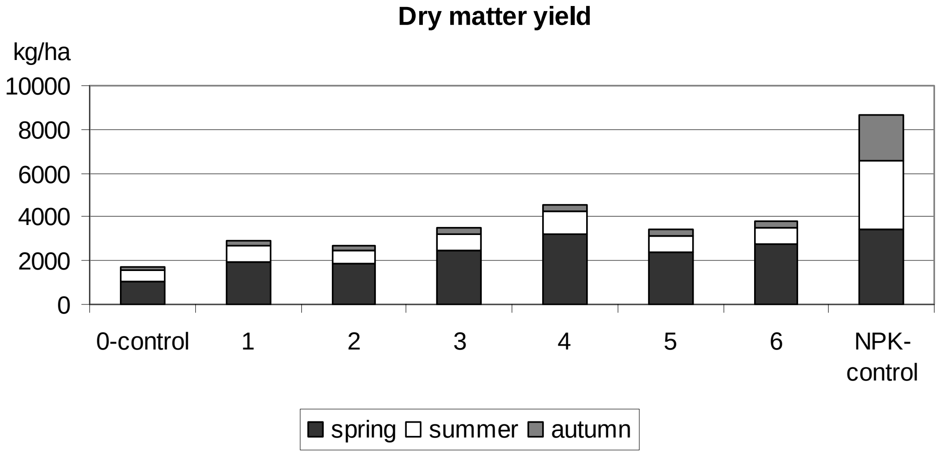

Figure 4. Dry matter yields of three cuts in 2003 on the compost and granule treatments (1-6) and control treatments (0-control and NPK-control). 1 biowaste compost, 2 biowaste compost + uncleaned ash granules, 3 biowaste compost + cleaned ash granules, 4 biowaste sewage sludge compost, 5 biowaste sewage sludge compost + uncleaned ash granules, 6 biowaste sewage sludge compost + cleaned ash granules.

3. CONCLUSIONS

The results show that the tumble (layering) agglomeration method is suitable for the production of fly ash-compost granules, which are distributable and improve the usage and quality of granule raw material. With the applied pelletizing method no differences were observed between the use of unprocessed fly ash and that of fractionated fly ash, on the one hand. On the other hand, the compost waste quality had a significant effect on the pelletization result. Regardless of the prescreening process, the waste compost material still contained sticks and fibre bundles, or other quality deviations and significant moisture variations. The compost-ash pellet size and form varied to a significant extent, but the pellets remained distributable, however. According to the compressive strengths, the pellets produced were not very durable, but withstood handling to a certain extent. In addition, pelletizing enhanced the processability of the material and reduced the amount of dust generated. Mixing waste composts with ash increased the contents of main nutrients, except for nitrogen, and thus enhanced the usability of waste materials in plant production. On the other hand, mixing with processed ash proved to be better than mixing with unprocessed ash, since the trace element contents were lower with processed ash. The deficiency of nitrogen needs to be resolved with additional fertilization when applying waste compost granules in plant production.

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