Evaluation of Maturity of Various Composted Materials

By AKIO INOKO

Department of Natural Resources, National Institute of Agro-Environmental Sciences
(Yatabe, Ibaraki, 305 Japan)

In recent years, from the viewpoints of saving chemical fertilizers and recycling organic matter, more complex types of organic matter have been applied to cropland, including materials both within and outside the agricultural system. From the agricultural point of view, an extensive and detailed knowledge is needed of the quality of these organic materials.

Raw materials of this kind nearly always receive some treatment before they are applied to cropland, since organic matter at an early stage of decomposition can damage crops by immobilization of nitrogen, by toxic substances, and causing deteriolation of soils through marked soil reduction.

In order to hasten the decomposition process, it is common to pile organic raw materials, with a sufficient supply of water and air, that is to compost them. Although the importance of maturity of compost has long been recognized, it is often difficult to know when the compost reaches maturity in fact, that is, to evaluae maturity of composting materials.

In this paper, the present author intends to describe outlines of evaluating practices of composted materials along with features of organic constituents of raw materials and their changing pattern during composting processes. The problem of evaluating maturity can be seen an urgent one for the users, but one of which we have little knowledge or experience.

Maturity of organic matter[8]

There is an urgent need to clarify the problem of maturity in various types of organic matter as already described. The concept of maturity, however, can be an ambiguous one, and is often given different meanings. In this paper, the present author defines maturity as the rotting of organic matter through biological reactions, to the extent that when the material is applied to cropland to increase soil fertility, its organic constituents have already stabilized to a large extent. In this way damage to crop plants is avoided, while enough energy is supplied for microbial activity to be taken place in the soils. The concept of maturity should include the extent of rotting, so that deterioration of the soil and the human environment is not caused by the application of composted organic matter. When rotting has progressed to this extent, the material can be regarded as completely matured. Various stages up to this complete maturity can be called the degree of maturity. Therefore, the concept of maturity can be understood as an agricultural term, with a definite purpose. To clarify problems of maturity, we need indices and criteria of maturity of particular types of organic matter.

The property of this consideration can be shown as the following example.[9] Fig. 1 shows the changing pattern of organic constituents of rice straw during its composting process. Accompanying with progress in rotting, total carbon contents, hemicellulose and cellulose contents decreased whereas total nitrogen, crude ash, and lignin contents increased. The damage of crop plants and deterioration of soils due to application of immature rice-straw compost of this kind appear as nitrogen starvation of crop plants

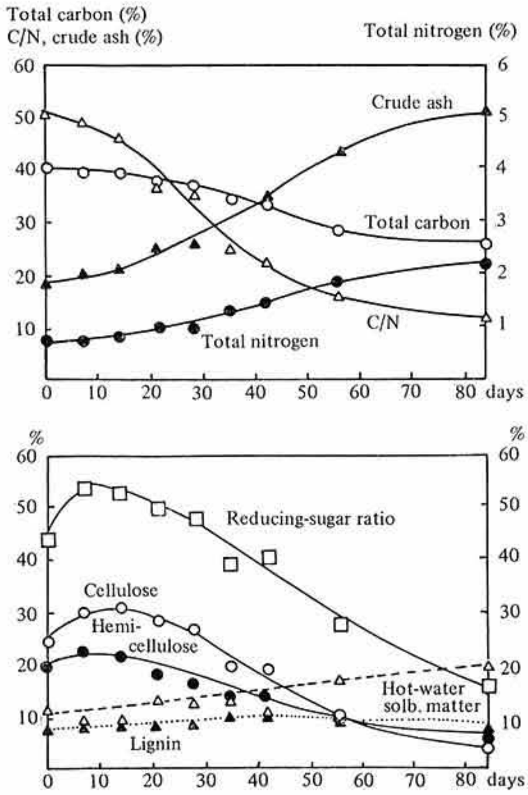

Fig. 1. Changing pattern of organic constituents of rice straw during piling

after extremely severe immobilization of nitrogen and marked soil reduction. Therefore, causal substances of damage are easily-decomposable carbohydrates. Furthermore, main purpose of composting is to reduce carbohydrate contents by rotting to some extent. From the results of Fig. 1 and criteria of maturity described below, it is considered that after rotting is continued to 60 days with frequent turning of the heap, the material can be regarded as completely mature. Further rotting by piling for longer period is considered to be meaningless to prevent damage of crop plants by application of the materials, and this excessively longer rotting causes much loss of carbohylrates which are sources of energy for microbial activities.

From the fact above mentioned, the following items are necessary to settle indices and criteria of maturity of composts, and also develop a simplified check method of maturity: organic constituents of raw materials and their changing patterns during composting, main cause of damage of crop plants when immature compost is applied, and main purpose of maturation.

Organic constituents of some typical organic raw materials

Table 1 shows organic constituents of eight kinds of typical organic raw materials.[9] The total carbon content varies markedly according to the ash content, ranging from 27 to 54%. Total nitrogen content ranges widely from 0.3 to 5.3%, and is low in bark and rice straw and high in animal wastes and sewage sludge. Consequently, carbon-nitrogen ratios are distributed over an even wider range from 7 to 207, reflecting total carbon and nitrogen contents. The ratios are high in bark and rice straw and low in animal wastes and sewage sludge.

The levels of hemicellulose and cellulose, and lignin also varies greatly in different kinds of organic raw materials. The hemicellulose content covers a range from 6 to 23%, and that of cellulose from 4 to 26%. A high cellulose content is found in bark, municipal refuse, and poultry waste mixed with woody materials, while a low content is found in animal wastes and sewage sludge. The lignin content is distributed over a range from 6 to 38%, and is highest in bark and poultry waste mixed with woody materials.

The organic constituents thus vary markedly in different kinds of organic raw materials. The eight kinds of materials can be classified into three groups, according to their main organic constituents. The first group contains woody materials such as bark and saw dust, which are high in lignin content and low in nitrogen content. The second group contains cellulosic materials with a high hemicellulose and cellulose contents and very low lignin content, such as rice straw and municipal refuse. The third group comprises nitrogenous materials such as animal waste and sewage sludge, containing a high level of

Table 1. An example of organic constituents of various organic matter (raw materials)

Organic matter	Total carbon (%)	Total nitrogen (%)	C/N ratio	Crude ash	Hot-water soluble org. matter	Carbohydrates		Lignin (%)
						Hemi-cellulose	Cellulose	
Bark (western hemlock)	53.9	0.26	207.3	6.2	7.1	11.7	21.9	38.1
Rice straw	41.3	0.81	51.0	18.8	11.7	20.6	24.7	7.7
Municipal refuse	40.8	1.64	24.9	23.6	22.1	9.6	25.6	14.7
Poultry waste mixed with woody materials	40.9	1.24	33.0	18.9	—	18.9	25.4	22.9
Animal wastes								
Poultry	33.3	4.98	6.7	24.6	—	22.2	4.5	8.9
Swine	44.8	5.32	8.4	16.4	—	23.4	3.6	20.1
Cattle	32.9	2.03	16.2	16.5	—	23.0	6.1	20.5
Sewage sludge	27.2*	3.13	8.7	47.8	12.8	6.1	9.5	6.0

Percentage calculated on oven-dry basis.
* Organic carbon

nitrogenous compounds and low cellulose content. These differences make it clear that these groups are also likely to be different in the purpose of making them mature, particulary in the purpose of application of their end-product to soils.

Evaluation of maturity of each organic raw material

1) Woody materials

These materials usually decompose only slowly and have high carbon-nitrogen ratios ranging from 100 to over 1,000.[1] However, nitrogen immobilization and soil reduction do not result to any marked extent from the application of these materials, because of their slow rates of decomposition. Resins, terpenoids, and phenolic substances derived from woody materials are often regarded as injurious to crop plants, but reliable experimental results are not yet available.

Composting is usually operated by piling with sufficient turning these woody materials over six months with addition of suitable nitrogen sources such as chemical fertilizers or animal wastes. Main purpose of piling is considered to decompose harmful substances above mentioned and kill pathogenic microbes and others through high temperature accompanying with progress of decomposition. The criteria of maturity in such materials, which decompose very slowly, are difficult to define at present. Duration of piling, turning, temperature elevation at initial stage of the piling can be indirect measure of maturation.

2) Cellulosic materials

Cellulosic materials contain high level of hemicellulose and cellulose. When immature cellulosic materials are applied to cropland, nitrogen starvation occurs in crop plants as the result of severe nitrogen immobilization. Violent soil reduction also takes place, caused by rapid consumption of oxygen by soil microbes. The main purpose in piling cellulosic materials is to decompose carbohydrate to a suitable extent. For this reason, the carbon-nitrogen ratio is traditionally used to check the degre of maturity.

(1) Rice straw

Kumada[10] examined the mineralization and/or immobilization of nitrogen by means of a series of incubation experiment, using various organic raw materials with different carbon-nitrogen ratios. From the results of this experiment, Kumada ascertained that immobilization of nitrogen does not occur in materials with carbon-nitrogen ratio lower than 20. Fig. 1 shows that nitrogen content gradually increases during the composting process, while carbon content decreases. Well-matured rice-straw composts usually have nitrogen contents higher than 2% on oven-dry basis. This level was also proposed by Okuda[11] as a criterion of maturity in rice-straw compost.

Fig. 1 also shows marked decrease of hemicellulose and cellulose contents as composting proceeded. Assuming that the carbon content of reducing sugar is 40.0%, the reducing sugar ratio can be calculated as follows:[7]

$$\text{Reducing sugar ratio (\%)} = \frac{\text{Hemicellullose (\%)} + \text{Cellulose (\%)} \times 0.4}{\text{Total carboh (\%)}} \times 100$$

The many analyses of the organic constituents of straw at various stages of decomposition have also shown that well rotted organic matter of this kind with a carbon-nitrogen ratio lower than 20 and a total nitrogen content higher than 2% also have a reducing sugar ratio lower than 35%.

From the results of these experiments, a tentative indices and criteria of the maturity of straw compost can be proposed as follows:

i) The carbon-nitrogen ratio should be below 20,

ii) Total nitrogen should be higher than 2% on oven-dry basis,

iii) The reducing sugar ratio should be below 35%.

A simple method of checking maturity of these cellulosic materials including rice-straw compost is available in the traditional diphenylamine test to examine the formation of nitrate nitrogen.

During a composting of rice straw, there is a gradual increase in cation-exchange capacity of the organic fraction. The method developed by Harada and Inoko[3,4] showed that well-matured straw compost which satisfies the above mentioned criteria of maturity would have the cation-exchange capacity higher than 100 me/100 g of organic matter (on ash-free basis). The cation-exchange capacity can also be used as a measure of maturity, so far as rice-straw compost is concerned, but it varies in different kinds of raw organic matter. Consequently, values obtained for rice-straw compost can not be applied as a test of maturity to other kinds of organic matter. The paper chromatographic method[5,6] described below can not be applied to straw compost.

(2) Municipal refuse

Changes in the organic constituents of municipal refuse during composting[8,9] are very similar to those of rice straw. From these results, the criteria of maturity for municipal refuse can be considered as similar to those for rice straw, that is, the carbon-nitrogen ratio should be lower than 20, the total nitrogen content should be above 2% (on oven-dry basis), and the reducing sugar ratio should be below 35%.

The following simple methods are proposed for testing the municipal refuse compost. The paper chromatographic method following the description of Hertelendy,[5] using circular filter paper containing silver nitrate and al-

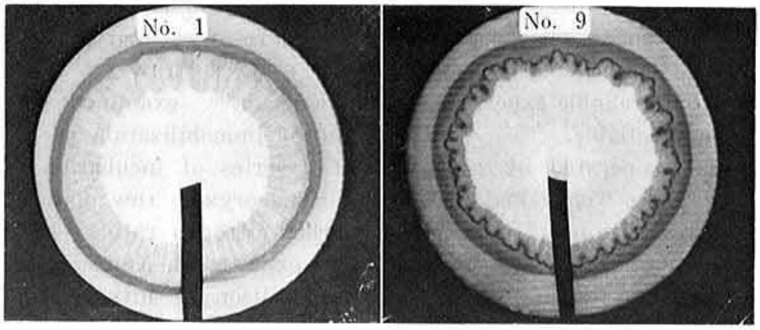

Plate 1. Chromatogram of municipal refuse compost
No. 1. Raw materials
No. 9. Compost after 60 days' pilling and turning

kali extract of composted material, is one of the most useful. As shown in Plate 1,[6] chromatograms from well-matured compost showed clear jagged part in peripheral part, whereas none was observed in chromatograms from immature compost and raw materials. Results are usually obtained within thirty minutes. Furthermore, color change in municipal refuse during composting process can be analyzed to test its maturity, using color analyzer to measure the surface color reflectance of powdered municipal refuse compost, and then calculating the stimulus value Y (degree of lightness). There is a positive correlation between stimulus value Y and the carbon-nitrogen ratio so that stimulus value can be used as a criterion for determining the degree of maturity in compost made from municipal refuse.[13] The cation-exchange capacity of well-matured municipal refuse compost which satisfies the three criteria given above increases to over 60 me/100 g (on ash-free basis).[3,4] This value can also be used as an index of maturity.

3) Nitrogenous materials

Damage to crop plants following the application of immature animal wastes was caused by explosive decomposition of easily-decomposable nitrogenous fractions. The same cause can be considered for sewage sludge. The main purpose of composting is to decompose these fractions to some extent before use. Additional advantages in piling wastes are regulation of water content and killing pathogenic microbes.

It is not possible at present to define criteria of maturity common to these nitrogenous wastes. Matsuzaki[12] found that the quantity of carbon dioxide produced by animal wastes reached the maximum within few days with marked temperature elevation, and the quantity levelled off after two weeks. Therefore, duration of piling with enough turning over three months and temperature elevation above 70°C can be indirect measures of maturity.

Beside these indirect methods of evaluation, there are some methods proposed for individual composts. The paper chromatographic method is useful for poultry and swine wastes but not effective for cattle wastes. Carbon-nitrogen ratio (below 16) and reducing sugar ratio (less than 35%) are useful criteria of maturity in cattle-waste compost.[2] Except poultry waste, diphenylamine test can also be used as a simple check method of nitrogeneous composts.

Conclusion

At present, indices and criteria of maturity in organic composts, in terms of their organic constituents and changes during piling, have not yet been defined, except for a few types of organic matter such as rice-straw compost and minicipal refuse compost. Simple methods for checking maturity of various composts are not sufficiently created. Therefore, the maturity problem of the majority of organic composts remained to be solved urgently. It can be predicted that the types of organic matter applied to cropland will become even more complex in the future, and will include materials from a number of sources. It is hoped that criteria of maturity will be established for a wide range of composted organic materials in terms of their organic constituents, and that rapid tests which can be carried out in the field will be found out.

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(Received for publication, October 31, 1984)