定置式 콤포스트化에서 添加物의 空隙率測定에 관한 研究

Some Measurements of Pore Space for Bulking Agents Used in Static Pile Composting

洪 志 亨*·松 田 從 三**·池 內 義 則**
Hong, Ji Hyung · Matsuda, Juzo · Ikeuchi, Yoshinori

摘 要

農畜產 廢棄物을 好氣性 醱酵處理하여 土壤에 還元利用을 目的으로 콤포스트(Compost)化 할 때에 空隙率(Pore space)에 미치는 物理的인 諸 性質의 相互關係를 究明 하고저 實驗을 遂行하였다.

本 硏究는 여러가지 水準의 壓縮力에 따른 添加 材料의 空隙率 變化 過程을 測定하고 이와 동시에 서로 다른 5種類의 材料別 粒子 크기에 對하여 含水率, 容積 重量, 容積 密度 및 粒子의 大小가 空隙率에 미치는 影響을 調査分析 하였으며 그 結果는 아래와 같다.

1. 細粒子 材料의 容積 密度는 粗粒子보다 더욱 크게 나타났다.
2. 含水率과 容積 重量이 增加하면 容積 密度는 커지나 空隙率은 減少하였다.
3. 空隙率은 含水率과 容積 重量보다 添加材料의 粒子크기와 大小分布에 더욱 커다란 影響을 받고 있었다.
4. 含水率이 55~65%이고, 容積重量이 0.25~0.33g/cm³이며 粒子의 크기가 1.5~5cm인 範圍內의 效率的인 콤포스트化에 있어서 空隙率은 65~80%의 범위를 形成하고 있음을 알 수 있다.

INTRODUCTION

Modern composting of rural waste is designed to be an aerobic process based on the turned and static windrow pile. For it is possible that we get rid of foul odours rapidly and efficiently when we use the above method under the aerobic conditions. The amount of aeration required varies with the physical nature of the composting material and with the aerating efficiency of the equipment and the nature of the system (Golueke, 1980).

A deficiency of pore space generally or locally in a compost pile can result in anaerobic conditions that create undesirable odors in the surrounding environment. As a general rule, the higher the moisture content of the organic material, the greater is the need to maintain a large pore space volume to assure adequate aeration. In the actual windrow compost pile, compression occurs differently through the height of the pile. Hence, there is a decrease in pore space. Singley (1982) found that the pore space of a mixture of the dewatered sludge and bulking agent is dependent mainly on their individual porosities, the mixture ratio, the moisture content of each material, and bulk weight of the mixture on a process of static pile sludge composting.

The pore space on the mixture one part wood chips and one part sewage sludge by volume was 51 percent at 63.2 moisture content in per-

* 順天大學 農業機械工學科
** 日本 北海道大學 農業工學科

cent.

A large decrease in pore space will result from a mix ratio of less than 1 : 1. When the moisture content changes, the bulk weight and pore space also change. The main environmental factors affecting to the aerobic composting process are moisture and aeration through pore space.

The pore space is expressed in the air volume percentage per unit volume, but the air space represents the air ratio occupied by porosity in liquid and air.

Hong et al. (1983) found that opimal bulk weight should be 0.25 to 0.33 g/cm³ at moisture content in the range of 55 to 65 percent. Fine particle size and uniform distribution of bulking agent were more difficult to aerate than coarse ones such as rice straw. According to Golueke (1980), generally particle sizes within the range of 1 or 2cm to about 15cm are satisfactory.

Diaz et al. (1980) reported that the range of maximum permissible sizes is from 1.25 to 5cm with their experience.

This study is to discuss the effect of moisture content, bulk weight and particle size on pore space for various bulking materials. It is very essential that we should know the physical factors which have an influence upon the pore space based on the open and enclosed compost system in the solid composting process of the investigation into the amount of pore space.

The objectives of the investigation reported in this paper were to determine experimentally how pore space changes according to the level of compression pressures and to measure a relationship between pore space and physical characteristics of composting materials for engineering design. Also we hope to determine a suitable aeration criteria for the solid composting process system.

APPARATUS AND PROCEDURE

The apparatus used for the pore space test was an actual volume measuring instrument. Model DIK-100. The bulk weight tester, as shown in Figure 1, consisted of a pressure rod 5cm in diameter and 18cm in length with a 13cm diameter disc plate attached. Weights ranging from 370 to 6552 gm were suspended above a pressure plate (20cm²) attached to the handle of the stand. The handle lowered the weight and pressure mechanism upon sampling ware (not shown) containing compost samples. The sampling ware used to determine pore space and bulk weight had a 100cc volume. Compost materials with different particle sizes and moisture contents, ranging from 8-80gm were placed in the sampling ware to determine pore space and bulk weight.

Physical properties of different bulking materials are shown in Table 1. Rice hulls (Rh). rice straw (Rs), wheat straw (Ws), sawdust

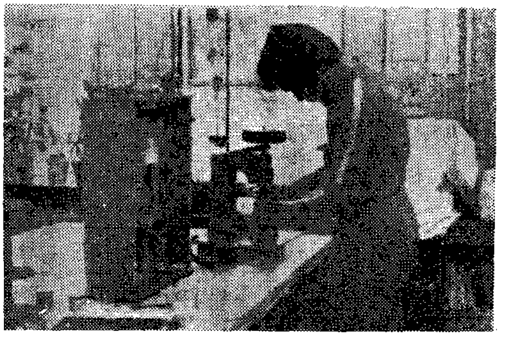

Fig. 1. Experimental apparatus and measuring instruments

Table-1. Physical properties of bulking materials

Determinations	Raw manure	Rice straw	Rice hulls	Wheat straw	Sawdust	Bark
Moisture in %	86.5	11.0	11.5	10.8	11.2	10.8
Particle size in cm.	0.02	1.5 to 5.0	0.6	1.5 to 5.0	0.2	0.4 to 3.0

(St), and bark (Bk) with known particle size and moisture content were evaluated to determine the effect on pore space. Samples of each material weighing 1 kg were conditioned by adding water to obtain four moisture contents of 30, 50, 60, and 70 percent on a wet basis. In addition, samples of Run No. 8 were mixed manually to obtain four ratios of 1 : 2, 1 : 1, 3 : 2, and 2 : 1 on a wet weight basis of dairy manure to rice straw (particle size: 1.5cm).

Values of pore space were calculated using the following equation:

$$Ps=(1-Va/Vt)\times 100\% \quad \cdots\cdots(1)$$

where,

Ps=Pore space, %

Vt=Total volume, cm^3

Va=Actual volume, cm^3

The bulk weight is expressed as the wet weight of bulking material per unit volume. The bulk density value has frequent appilcation in engineering for calculating compaction and volume. This represents the dry weight of the bulking material per unit volume of solids and voids occupied by the original. Bulk density was calculated using the following equation:

$$Bd=Bw\times Dm(\%)/100 \quad \cdots\cdots(2)$$

where,

Bd=Bulk density, g/cm^3

Bw=Bulk weight, g/cm^3

Dm=Dry matter, %

A 10gm sample was placed into the sampling can and weighed, dried overnight at 105°C in an electric drying oven and dry weight and moisture content determined afterward.

Samples of compost material were placed in the sampling ware and slowly compressed three times at a given pressure by a ram rod to assure compaction uniformity. The compost materials in the sampling ware were weighed actual volume measured, and pore space calculated. Most tests were conducted on bulking materials and their mixtures. Results are reported as the average of three tests.

RESULTS AND DISCUSSION

The results of the bulk weight, density and pore space tests are shown in Table 2. The decrease in pore space due to increment of moisture content and bulk weight. The lowest bulk densities occurred at the fine particle size.

Decrease in the bulk density of bulking material has the effect of significantly increasing the pore space. It appeared that increasing the moisture content and bulk weight increased bulk density but, decreased pore space. This phenomenon is characteristics of porous material. A trend lower density values at larger particle size as about 5.0cm and higher density value of sawdust as 0.2cm are apparent. It is

Table-2. Changes in bulk weight and bulk density of the various bulking material by the loading pressure rate and moisture content

Loading pressure	Moisture conditions in % (w.b.)							
rate in kg/cm^2	Bw	Bd	Bw	Bd	Bw	Bd	Bw	Bd
Test Run No.1	Rice hulls (0.6cm)							
	25.38		46.08		56.47		67.05	
0.02	0.11	0.08	0.17	0.09	0.22	0.09	0.26	0.09
0.03	0.12	0.09	0.17	0.09	0.23	0.10	0.30	0.10
0.04	0.12	0.09	0.18	0.10	0.23	0.10	0.30	0.10
0.07	0.12	0.09	0.18	0.10	0.23	0.10	0.30	0.10
0.14	0.13	0.10	0.20	0.11	0.25	0.11	0.34	0.11
0.33	0.14	0.10	0.23	0.12	0.28	0.12	0.36	0.12

Test Run No.2 Rice straw (1.5cm)

	29.98		46.32		58.25		68.04	
0.02	0.12	0.09	0.17	0.09	0.22	0.08	0.30	0.10
0.03	0.14	0.10	0.17	0.09	0.22	0.09	0.31	0.10
0.04	0.14	0.10	0.19	0.10	0.23	0.09	0.32	0.10
0.07	0.16	0.11	0.20	0.10	0.24	0.10	0.33	0.11
0.14	0.16	0.12	0.20	0.11	0.26	0.11	0.37	0.12
0.33	0.20	0.14	0.26	0.14	0.30	0.13	0.40	0.13

Test Run No.3 Rice straw (5.0cm)

	28.14		46.64		57.84		68.56	
0.07	0.08	0.06	0.13	0.07	0.15	0.07	0.21	0.07
0.14	0.09	0.07	0.14	0.07	0.18	0.07	0.26	0.08
0.33	0.12	0.08	0.17	0.09	0.21	0.08	0.31	0.10

Test Run No.4 Wheat straw (1.5cm)

	27.94		46.55		55.47		67.54	
0.02	0.09	0.07	0.13	0.07	0.24	0.10	0.26	0.08
0.03	0.10	0.07	0.14	0.06	0.26	0.11	0.28	0.09
0.04	0.11	0.08	0.14	0.08	0.27	0.11	0.32	0.10
0.07	0.11	0.08	0.16	0.09	0.29	0.12	0.33	0.11
0.14	0.12	0.09	0.18	0.10	0.29	0.13	0.40	0.13
0.33	0.14	0.10	0.23	0.12	0.34	0.15	0.49	0.16

Test Run No.5 Wheat straw (5.0cm)

	28.20		47.98		59.13		75.46	
0.02	0.04	0.03	0.05	0.03	0.06	0.03	0.12	0.03
0.03	0.05	0.03	0.08	0.04	0.13	0.05	0.16	0.04
0.04	0.06	0.04	0.09	0.05	0.13	0.06	0.19	0.05
0.07	0.07	0.04	0.11	0.06	0.16	0.07	0.21	0.05
0.14	0.11	0.06	0.13	0.07	0.17	0.07	0.23	0.06
0.33	0.14	0.08	0.13	0.07	0.20	0.08	0.28	0.07

Test Run No.6 Sawdust (0.2cm)

	37.96		54.05		62.28		71.43	
0.02	0.31	0.19	0.43	0.20	0.47	0.18	0.63	0.18
0.03	0.33	0.20	0.45	0.21	0.50	0.19	0.66	0.18
0.04	0.35	0.22	0.47	0.21	0.53	0.20	0.67	0.19
0.07	0.36	0.22	0.48	0.22	0.54	0.20	0.71	0.20
0.14	0.38	0.23	0.51	0.24	0.60	0.23	0.73	0.21
0.33	0.40	0.25	0.59	0.27	0.63	0.24	0.82	0.23

Test Run No.7	Bark (0.4 to 3.0cm)							
	34.91		49.59		58.07		66.24	
0.02	0.17	0.11	0.28	0.14	0.31	0.13	0.50	0.16
0.03	0.19	0.12	0.31	0.16	0.38	0.16	0.51	0.17
0.04	0.23	0.15	0.32	0.16	0.39	0.17	0.57	0.19
0.07	0.24	0.16	0.34	0.17	0.46	0.19	0.63	0.21
0.14	0.27	0.18	0.38	0.19	0.48	0.20	0.66	0.22
0.33	0.30	0.20	0.43	0.22	0.54	0.23	0.78	0.26

Test Run No.8	Mixed raw dairy manure with rice straw (1.5cm)							
	32.87(1 : 2)		46.93(1 : 1)		50.43(3 : 2)		58.68(2 : 1)	
0.02	0.13	0.08	0.14	0.08	0.19	0.10	0.26	0.11
0.03	0.13	0.09	0.16	0.09	0.19	0.10	0.28	0.12
0.04	0.14	0.09	0.18	0.09	0.19	0.11	0.29	0.12
0.07	0.15	0.10	0.20	0.11	0.20	0.12	0.32	0.13
0.14	0.17	0.11	0.21	0.12	0.24	0.13	0.36	0.15
0.33	0.19	0.13	0.25	0.13	0.26	0.14	0.40	0.16

Note: 1) Bw : Bulk weight (g/cm³), Bd : Bulk density (g/cm³).
2) Figures in parentheses give the mixing ratio by the wet weight.

obvious that the bulk density of fine particle size is greater than coarse ones. The variation in bulk density should be influenced by moisture content, bulk weight and particle size of the composting materials.

Singley (1982) reported that when the moisture content changes, the bulk weight and pore space also change. This report is a similar trend with the results.

The relationship between moisture content and pore space is plotted in Fig. 2, 3, and 4. Although the pore space of the bulking material varies with both moisture content and bulk weight, the change in pore space is due to particle size much more than moisture and bulk weight. Larger particle size as 5.0cm have only

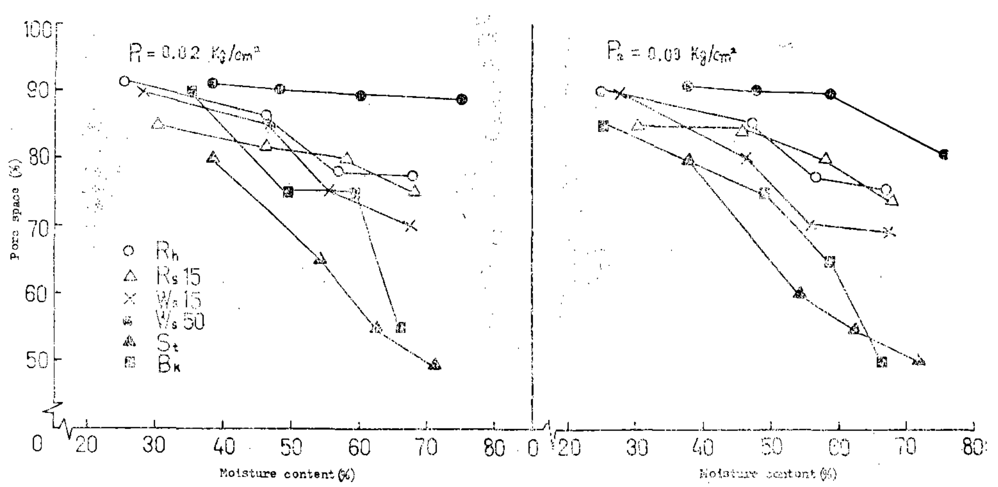

Fig. 2. The effect of moisture content on bulking agents pore space at lower pressures.

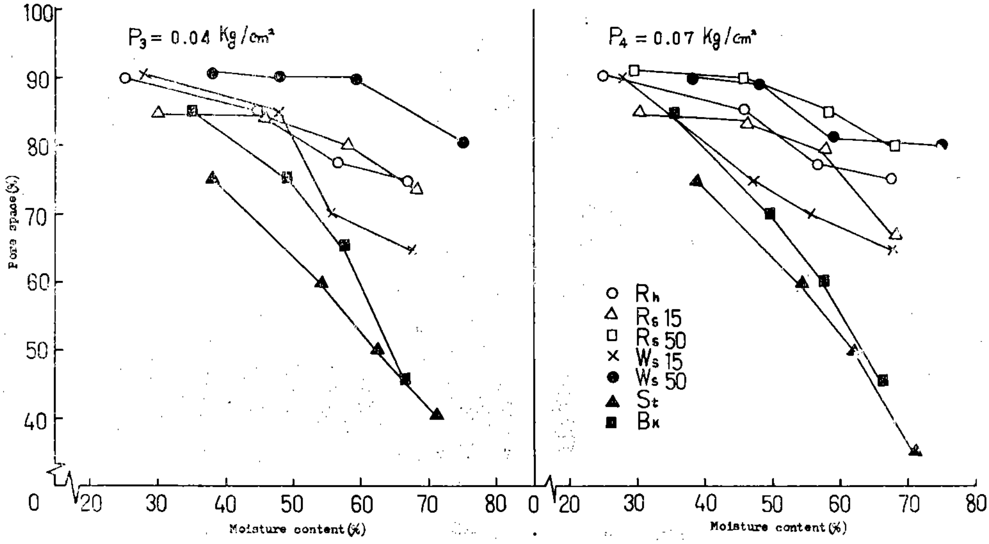

Fig. 3. The effect of moisture content on bulking agents pore space at middle pressures

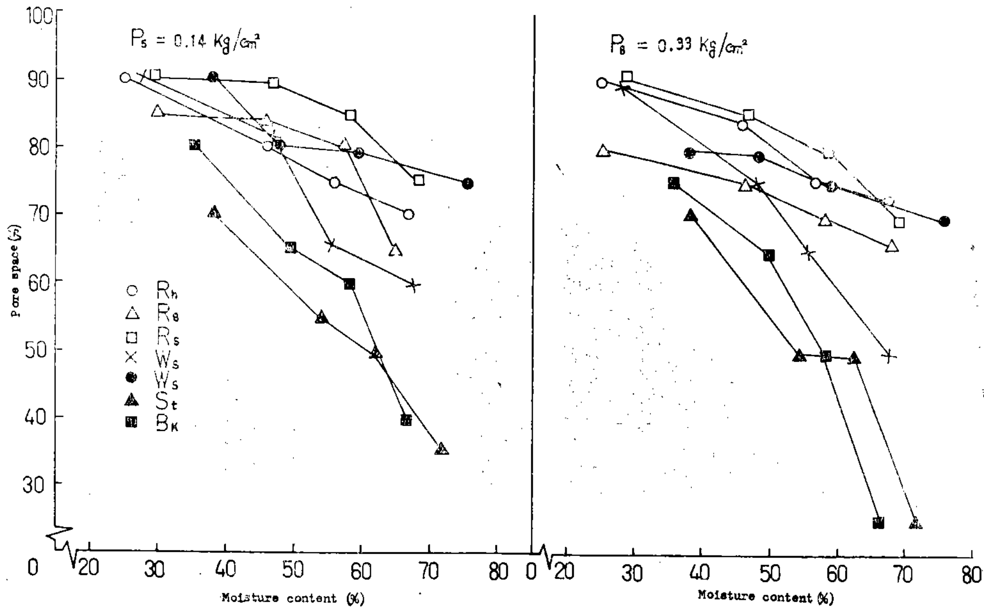

Fig. 4. The effect of moisture content on bulking agents pore space at higher pressures

a slight effect on pore space, but the fine particle size such as sawdust and bark indicated that compression pressure have a significantly effect on it.

Generally, the pressure rate decreases, the pore space increased, and also the pore space slightly decreased with a increase in moisture content.

The pore space of the bulking material displayed a very regular pattern.

This is due to the fact that at higher moisture contents, pore space represent a lower proportion of the porosity.

Particle size is one of the important environmental factor affecting the pore space involved in the composting process. To check the value of pore space for five different particle sizes at the suitable moisture content as approximately 60 percent, the pore space values were determined for the data with results as follows:

	particle size (cm)	pore space (%)
at,	0.2	50-55
	0.4-3.0	50-65
	0.6	75-78
	1.5	65-80
	5.0	80-90

The curves shown in figures 2, 3, and 4 demonstrate the pore spaces recorded for sawdust and bark. In general, the value of pore space in fine particle size such as sawdust (0.2cm), bark (0.4-3.0cm) was particularly lower than the others. Both the size and nature of the bulking material were important in composting from the experiments mentioned above. Furthermore, pore space was greatly affected by the moisture content. Hong et al. (1983) found that the fine particle size of bulking material is more difficult to aerate than coarse ones. Particle size within the range of 1 or 2cm to about 15cm is satisfactory (Golueke, 1980).

The range of maximum permissible sizes is from 1.25 to 5cm in composting municipal solid waste by the research of Diaz et al. (1980). These reports were similar to our results. Therefore, the favorable pore space condition for the solid composting process under the particle size within the range 1.5cm or more to around 5cm was in the range of 65 to 80 percent as shown in Figs. 2, 3, and 4.

The other hand, pore space of the fine and uniform distribution of particle size such as sawdust (0.2cm) was significantly lower value as 50 to 55 percent.

Singley (1982) reported that the pore space on the mixture of the wood chips and sludge was 51 percent at 63.2 moisture content in percent. This value was similar to our results.

As shown in Fig.5, a comparison of the loading pressure rates shows that the pore space of the composting material decreased continually in accordance with the increasing loading pressure rate and wet weight mixing ratio.

These results represented that pore space is determined by the pressure rate and wet weight

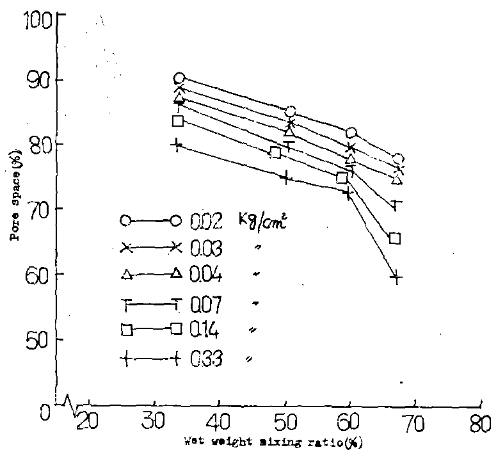

Fig. 5. Relationship between pore space and mixing wet weight of dairy manure to rice straw under 15mm particle size

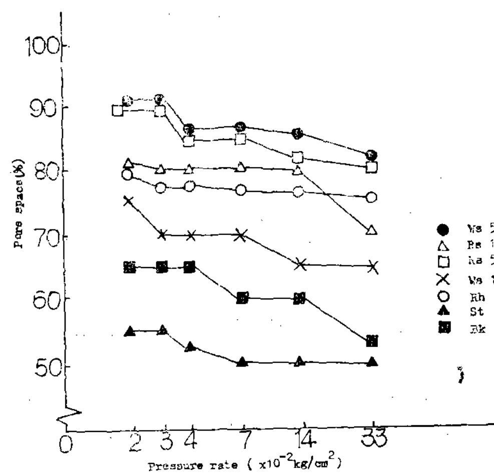

Fig.6. Relationship between pore space and pressure rate under 60% (w.b.) moisture content

mixing ratio (moisture content). In general, the pore space is apparently lower at the higher pressure rate and moisture content.

This result also agreed with the reports worked by Singley (1982). The pore space remained slightly decrease within the range of 0.02 to 0.33kg/cm² loading pressure rate. On the other hand the pore space is remarkably different from the nature of raw material as shown in Fig. 6. Furthermore, pore space range of sawdust was generally lower than that obtained for the others.

This indicates that pore space was not greatly affected by the loading pressure. From this relationship it follows that pore space is determined primarily by two factors, particle size and the nature of bulking material. Pore space can be controlled by measuring the loading pressure, moisture content, particle size and the nature of composting material.

SUMMARY AND CONCLUSIONS

This study was conducted to measure changes in the pore space of bulking materials subjected to various compression pressures as well as to investigate the effect of moisture contents, bulk weight, bulk density, and particle size on pore space for five different particle sizes.

The following conclusions can be made from this study:

1. The bulk density of fine particle size material was greater than coarse particle size material.
2. Increasing the moisture content and bulk weight increased bulk density, but decreased pore space.
3. Pore space was more more affected by the particle size and size distribution of the bulking materials than the moisture content and bulk weight.
4. For efficient composting, a moisture content ranging from 55 to 65 percent, a bulk weight from 0.25 to 0.33g/cm³, and particle sizes ranging from 1.5 to 5cm will produce pore space ranging from 65 to 80 percent.

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