



On-Farm Composting Management

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INTRODUCTION

Composting is the controlled biological decomposition of organic matter. Composting differs from natural decomposition in that composting is controlled by humans. Organic materials are recycled whether or not we compost them, but well-managed composting, in which composting conditions are regulated and optimized so that composting microorganisms can thrive, ensures a faster process and the generation of a quality end product.

This publication describes composting management practices starting from compost material preparation and ending with the evaluation of the finished compost. It explains how to determine the best mixes of feedstock materials, how to manage compost piles for good aeration, how to manage pile moisture and odor, and how to check the finished products.

Numerous composting references are readily available to composting operators, and you are encouraged to get further information from the resources listed at the end of this document. Another good way to accumulate experience is to conduct small, on-farm trials using different mixes of feedstock materials and different management techniques under your specific conditions during different seasons of the year. A great deal can also be learned by visiting composting facilities and talking with operators about their methods and experiences. Readers interested in learning about the basics of composting are referred to *The Composting Process* (CIS 1179), available at <http://www.cals.uidaho.edu/edcomm/pdf/CIS/CIS1179.pdf>

DETERMINING COMPOST MIXES

Compost mixes should be based on feedstock properties such as C:N (carbon: nitrogen) ratios, moisture content, bulk density, and particle size. Depending on the intended use of your compost, you might determine your mixture based on observations and some experience with the raw materials or based on formulas and more precise characterizations of the composting raw materials.

Many composting operators managing for on-farm use determine their feedstock mix by its look and feel. With an eye to optimizing C:N ratio and moisture content and with some experience with the raw materials, this trial and error approach can often work. (Table 1 lists basic properties of potential raw materials.) For larger operations, or when composting needs to be more effi-

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This publication is second in a series on dairy manure compost production and use in Idaho. Find more information on animal waste management at the Idaho Nutrient Management website—www.extension.uidaho.edu/nutrient

cient, more precise compost recipes can be calculated using formulas (see formulas for determining composting recipes, page 3) and computer spreadsheets that are based on the characteristics of the raw materials.

Collect samples of feedstock carefully to ensure they represent the “typical” composition and moisture content of your feedstock. Samples that do not reflect the actual properties of the bulk materials, such as moisture content and C:N ratio, will lead to less than optimal composting results. Your final choice of materials often involves a trade-off among moisture content, porosity, and C:N ratio as shown in example 1, page 7.

BULK DENSITY

The formulas in the sidebar yield weight-to-weight ratios of materials. These can be converted using the bulk densities of the raw materials to volume-to-volume ratios for actual mixing. Some bulk densities are listed in table 1.

Bulk densities of specific feedstocks can also be estimated on-farm by weighing a couple of samples of the materials in a container of known volume. For the best estimation of bulk density, the materials should be packed into the container in a way that is similar to how they will be packed under composting conditions. Once the average weight has been calculated, the density can be estimated by dividing the average weight by the known volume (example 2, page 8).

MANAGING COMPOST PILES FOR GOOD AERATION

Aerobic microbes need an environment with at least a 5% oxygen content to survive and function. As microbial activity increases in a compost pile, the microbes will consume more oxygen. If the oxygen supply is not replenished, composting can shift to anaerobic decomposition, thus slowing the rate of the composting process and leading to foul odors.

Depending on your composting methods, aeration can be forced, passive, or done by turning piles. Regardless of the method of aeration, the amount of oxygen supplied to the compost pile may differ from the amount of oxygen that is actually reaching the microbes. The microbe-usable amount of oxygen depends on factors such as the moisture content of the compost materials and their surface area.

Microbes inhabit a thin liquid film on the surface of the compost particles. Because the diffusion coefficient of oxygen through water is significantly smaller than it is through air, oxygen may not be reaching the microbes at the rate they demand even though it is entering the pile at a sufficient rate. Keeping adequate air-filled porosity in composting piles is essential for aerobic composting.

If you use aerated static piles, your choices of pipe size and blower capacity, compost pile construction, initial mixing of materials, and particle size are critical for establishing sufficient and well-distributed airflow during the composting

Table 1. Common feedstocks and their characteristics.

FEEDSTOCK	MOISTURE CONTENT (% OF WET WEIGHT)	C:N (WEIGHT TO WEIGHT)	BULK DENSITY (POUNDS PER CUBIC YARD)
High in carbon			
Hay	8–10	15–30	
Corn stalks	12	60–70	32
Straw	5–20	40–150	50–400
Corn silage	65–68	40	
Fall leaves		30–80	100–300
Sawdust	20–60	200–700	350–450
Brush, wood chips		100–500	
Bark (paper mill waste)		100–130	
Newspaper	3–8	400–800	200–250
Cardboard	8	500	250
Mixed paper		150–200	
High in nitrogen			
Dairy manure	80	5–25	1400
Poultry manure	20–40	5–15	1500
Hog manure	65–80	10–20	
Cull potatoes	70–80	18	1500
Vegetable wastes		10–20	
Coffee grounds		20	
Grass clippings		15–25	
Sewage sludge		9–25	

Source: Cooperband, L. 2002. The art and science of composting. Center for Integrated Agricultural Systems, University of Wisconsin-Madison. <http://www.cias.wisc.edu/wp-content/uploads/2008/07/artofcompost.pdf> (accessed November 28, 2011).

FORMULAS FOR DETERMINING COMPOSTING RECIPES¹

FORMULAS FOR A SINGLE INGREDIENT

$$\text{Moisture content (\%)} = 100 \times (\text{total weight} - \text{dry weight}) \div (\text{total weight})$$

$$\text{Weight of water} = \text{total weight} \times \text{moisture content}$$

$$\begin{aligned} \text{Dry weight} &= \text{total weight} - \text{weight of water} \\ &= \text{total weight} \times (1 - \text{moisture content}) \end{aligned}$$

$$\text{Nitrogen content} = \text{dry weight} \times (\%N \div 100)$$

$$\% \text{ Carbon} = \%N \times (\text{C:N ratio})$$

$$\begin{aligned} \text{Carbon content} &= \text{dry weight} \times (\%C \div 100) \\ &= \text{N content} \times (\text{C:N ratio}) \end{aligned}$$

GENERAL FORMULAS FOR A MIX OF MATERIALS

$$\begin{aligned} \text{Moisture content (\%)} &= 100 \times \frac{\text{weight of water in (ingredient X + ingredient Y + ingredient Z + \dots)}}{\text{total weight of all ingredients}} \\ &= 100 \times \frac{(X \times m_x) + (Y \times m_y) + (Z \times m_z) + \dots}{X + Y + Z + \dots} \end{aligned}$$

$$\begin{aligned} \text{C:N ratio} &= \frac{\text{weight of C in (ingredient X + ingredient Y + ingredient Z + \dots)}}{\text{weight of N in (ingredient X + ingredient Y + ingredient Z + \dots)}} \\ &= \frac{[\%C_x \times X \times (1 - m_x)] + [\%C_y \times Y \times (1 - m_y)] + [\%C_z \times Z \times (1 - m_z)] + \dots}{[\%N_x \times X \times (1 - m_x)] + [\%N_y \times Y \times (1 - m_y)] + [\%N_z \times Z \times (1 - m_z)] + \dots} \end{aligned}$$

Where X, Y, Z are total weight of ingredients X, Y, and Z, respectively;

m_x , m_y , and m_z are moisture contents of ingredients X, Y, and Z, respectively;

$\%N_x$, $\%N_y$, and $\%N_z$ are % nitrogen of ingredients X, Y, and Z, respectively (% of dry weight);

$\%C_x$, $\%C_y$, and $\%C_z$ are % carbon of ingredients X, Y, and Z, respectively (% of dry weight).

FORMULAS FOR TWO INGREDIENTS

① Required amount of ingredient X per pound of Y based on desired moisture content:

$$X = \frac{m_y - M}{M - m_x}$$

Then check the C:N ratio using the general C:N ratio formula

② Required amount of ingredient X per pound of Y based on the desired C:N ratio

$$X = \frac{\%N_y}{\%N_x} \times \frac{R - R_y}{R_x - R} \times \frac{1 - m_y}{1 - m_x}$$

Then check the moisture content using the general moisture content formula

Where X is pounds of ingredient X per pound of ingredient Y;

M is desired mix moisture content;

m_x is moisture content of ingredient X (e.g., straw);

m_y is moisture content of ingredient Y (e.g., cattle manure);

$\%N_x$ and $\%N_y$ are % nitrogen of ingredients X and Y (% of dry weight);

R is desired C:N ratio of the mix;

R_x is C:N ratio of ingredient X;

R_y is C:N ratio of ingredient Y.

¹Source: Rynk, R. 1992. On-Farm Composting Handbook (NRAES-54). Cooperative Extension. Ithaca, N.Y.

process. Once the compost piles have been built, aeration can be adjusted only by controlling blowers based either on temperature or on a simple time schedule.

Aeration in turned windrows can be adjusted by turning the windrows to maintain the porosity necessary for adequate passive aeration and by adjusting windrow dimensions. For example, smaller windrows benefit aeration.

POROSITY

Porosity is defined as the volume of pores divided by the total volume of compost. Some of those pores will be filled with water and the rest with air. The initial pile mix should have between 45% and 65% air-filled porosity. During the active phase of composting, it shouldn't drop below 35%.

Porosity can be measured on-site by a bucket method (see sidebar, measuring porosity, and example 3, page 8).

FEEDSTOCK PARTICLE SIZE

The particle size of the feedstock will affect porosity, airflow, and the amount of microbial activity. Smaller particles have more surface area per unit volume and, therefore, microbes have more surfaces to colonize. However, if particles are too small, porosity will decrease, compaction will occur, and airflow within the compost pile will be restricted. Wood chips (<2 inches is preferred) can be added as a bulk material to increase pile porosity.

MEASURING POROSITY WITH THE BUCKET METHOD

Step 1. Place 5 gallons of water into a pail and mark the water level ("full line") on the inside of the pail. Empty the pail.

Step 2. Place the compost mix into the pail to the 5-gallon full line. For the best estimation of porosity, pack the compost mix into the pail in a way that approximates composting conditions.

Step 3. Add water to the pail until it reaches the full line. Record the amount you add. This added water is equal to the volume of voids.

The porosity (percent voids) in the compost media sample is determined with this formula:

$$\text{Percent voids} = 100 \times \frac{\text{Volume of water added (gallons)}}{5 \text{ gallons}}$$

Taking the average of multiple measurements (say, three repetitions) provides a better estimate than a single measurement.

PILE TURNING SCHEDULE

The pile turning schedule during composting varies from operation to operation depending on pile compaction, temperature levels in the pile, consistency of the compost mixes, labor and equipment availability, season, site size, and how soon the compost is needed. The number and frequency of turnings needed to achieve the desired quality of compost is best determined through experience. Some commercial compost producers turn their dairy manure compost windrows weekly.

PILE HEIGHT AND WIDTH

For a compost pile to heat up and stay hot, the minimum size of the pile should be 1 cubic yard. Beyond that, the ideal height and width of the piles should reflect ambient temperatures, properties of the raw materials (such as the particle size, bulk density, porosity, and moisture content), composting method, and your specific equipment (table 2). For example, a lower density, dry (<50% moisture) pile can be stacked higher than a wet, dense pile without the risk of developing anaerobic conditions within the pile. Small piles will be able to maintain higher internal oxygen concentrations than large piles, but large piles will retain heat better than small piles, an important consideration during winter months in Idaho when the ambient temperature is typically much lower than optimal composting temperatures (130–150°F).

Table 2. Compost pile sizing guidelines.

COMPOSTING METHOD	HEIGHT (FEET)	WIDTH (FEET)
Static piles	3–6	12
Passively aerated windrow system	3–6	10
Windrow composting		
Tractor pulled turner	6–8	10
Self-propelled turner	3–9	9–20
Bucket loader	6–12	10–20
Aerated static piles	6–12	10–20

Source: Cooperband, L. 2002. The art and science of composting. Center for Integrated Agricultural Systems, University of Wisconsin-Madison. <http://www.cias.wisc.edu/wp-content/uploads/2008/07/artofcompost.pdf> (accessed November 28, 2011).

MANAGING PILE MOISTURE

Measure compost moisture regularly throughout the composting process. An easy way to monitor compost pile moisture on farms is using moisture probes, for example, the REOTEMP Moisture Meter.

Generally, the ideal composting pile moisture content should be within 50% and 60% by weight during the active phase, the most rapid phase of decomposition. Water evaporates during the active phase of composting due to increased temperatures in the pile.

One principle behind the water loss is that warm air can hold significantly more moisture than colder air. Ambient air with

a lower moisture content enters the pile and picks up moisture as it warms. The warm, high-moisture content (saturated) air rises to the surface.

If the outside air temperature is low (i.e., winter time), a zone of equilibration forms near the surface of the compost pile. In this zone, part of the moisture in the warm, rising air condenses onto the surface of the compost materials. If the outside air temperature is high (i.e., summer time), the air rising from the pile has much more capacity for holding moisture, resulting in fast drying of the compost pile. This is what happens during the hot summer months in southern Idaho when the ambient air has a low moisture content (usually below 25% and often down to 15% or lower).

Adjust the moisture content within active composting piles based on ambient air moistures and temperatures. For example, compost piles could have a little lower moisture content (say, 50%) during winter months than in summer months.

If you are turning piles, you can add water as needed when you turn. If you are using static piles, it is best to make initial feedstock blends on the wet side, around 65–70% moisture content. Through trial and error, you can determine the initial moisture content that will keep the pile moist enough to keep microbes active. Some commercial composters using forced aeration systems add moisture by blowing humidified air through pipes into the piles.

The moisture content of mature compost is around 40%. If the moisture content is less than 30%, dust problems are more likely.

MANAGING ODORS IN COMPOST PILES

Effective odor management is based on an understanding of the question: Where do odors originate? Generally speaking, composting odors come from incoming raw materials (such as liquid manure and fish offal), stockpiled materials, poorly aerated compost piles, and standing pools of water around compost piles.

Most odors associated with the composting process are by-products of anaerobic decomposition and the transformation of organic materials by microbes. The principal odorous compounds include ammonia (with a pungent odor), hydrogen sulfide (with the odor of rotten eggs), volatile fatty acids, and indoles (with a fecal odor).

Under conditions that restrict the entry of oxygen into compost piles, such as high moisture content, overly large pile size, and minimal porosity, aerobic bacteria won't be able to get enough oxygen, causing odor-producing anaerobic bacteria to take over. You can minimize odors by managing pile aeration and moisture levels to promote active aerobic decomposition, as discussed above. Once aerobic conditions are reestablished, the bacteria will "eat" the odorous com-

pounds, resulting in the minimization of offensive odors.

Ammonia can form under both anaerobic and aerobic conditions, which mean that ammonia can form even in a well-aerated pile. If too little carbon is available in your feedstock or if nitrogen is available in excess (in other words, if the compost materials have a low C:N ratio), nitrogen is metabolized in such a way that gaseous nitrogen compounds (ammonia and nitrous oxide) are released, resulting in odors. To minimize odors from N compounds, it is important to incorporate carbon-rich materials (like straw) into nitrogen-rich materials (like dairy manure) to set compost pile initial C:N ratios well above 10:1 (25:1–35:1 is optimum).

Maintaining the compost pile pH below 7.5 also helps to prevent the release of ammonia gas. However, controlling pH within an optimal range is difficult and generally not attempted for on-farm composting.

Keeping compost sites free from standing pools of water around compost piles is another good management practice for reducing odors. This practice involves site selection, design, and preparation. It is best to choose a site that minimizes the risk of both run-on from the surrounding area and runoff to the surrounding area. (Runoff from the composting area must be contained and not allowed to flow off-site untreated.) A slope of about 2% for the composting site is desirable to prevent standing pools of water from forming.

Compost windrows should run up and down the slope, rather than across, to allow runoff water to move between the windrows rather than through them. The initial site preparation will usually require grading and may require surfacing to improve water movement from the site. Rain water and snow melt should also be diverted away from the sites by using diversion ditches.

Composting operations inevitably produce some odors, and if the operation is mismanaged, the odors can be offensive and may generate complaints from neighbors and passersby. Continual and conscientious efforts toward odor control are critical for a composting operation to be successful and sustainable.

CHECKING FINISHED PRODUCTS

Not all composts are created equal. Compost quality depends on many different factors such as the characteristics of the raw materials, environmental factors such as precipitation and ambient temperatures, management practices, and, most importantly, the intended use of the compost. Compost has many chemical, physical, and biological characteristics that allow it to be used in different ways. Table 3 shows typical ranges of test parameters in quality compost.

Table 3. Typical ranges of test parameters in quality compost.

TEST PARAMETER	RANGE
pH	6.8–7.3
C:N ratio	10:1–15:1
EC (soluble salts) 1:5 v/v method	0.35–0.64 dS/m (mmhos/cm)
Nitrogen	1.0–2.0% (by weight)
Phosphorus	0.6–0.9% (by weight)
Potassium	0.2–0.5% (by weight)
Moisture content	45–50% (by weight)
Organic matter	35–45% (by weight)
Particle size	passes 3/8" screen
Bulk density	900–1,000 lb/yd ³

Source: Warson, M. E. 2002. Testing compost. ANR-15-03. Ohio State University Fact Sheet. <http://ohioline.osu.edu/anr-fact/0015.html> (accessed November 28, 2011).

Compost maturity is gaining recognition as a significant parameter to use in evaluating compost. Immature and poorly stabilized composts pose problems during storage, marketing, and use. Immature composts in storage may become anaerobic, which often leads to the development of odors and/or toxic compounds as well as to bag swelling and bursting. Immature composts may heat up in pallets during shipment. Continued active decomposition when these composts are added to soil or growth media may reduce both oxygen and nitrogen in the soil root zone and introduce phytotoxic compounds, all of which may have negative impacts on plant growth.

During the early stages of composting, very little if any nitrate-N is formed. As the thermophilic (temperature above 105°F) stage ends, the mesophilic microorganisms, which function best at 75° to 105°F and convert organic N to ammonium-N and nitrate-N, begin to flourish. The appearance of significant quantities of nitrate-N (a couple of hundred ppm to over 1,000 ppm) is an indicator of mature compost. Therefore, measuring nitrate-N, along with other maturity tests such as the Solvita test, is a useful way to assess degree of maturity.

Compost producers and users must realize that different end uses (in organic fields, conventional fields, bedding, nurseries, landscapes, greenhouses, local and state highway right-of-ways, etc.) have different quality requirements, and the presently accepted methods to evaluate compost quality may not completely or precisely address the most important concern: Is the product appropriate for and does it perform well in the particular end-use? Testing different composts under real situations is the best way to judge their quality and is encouraged.

ADDITIONAL RESOURCES

PUBLICATIONS

- Christian, A.H., G.K. Evanylo, and J. W. Pease. 2009. On-farm composting—A guide to principles, planning, and operations. Virginia Cooperative Extension Publication 452–232.
- Cooperband, L. 2002. The art and science of composting. Center for Integrated Agricultural Systems, University of Wisconsin-Madison.
- Dougherty, M. 1999. Field guide to on-farm composting (NRAES-114). Cooperative Extension. Ithaca, N.Y.
- Moon, P. 1997. Basic on-farm composting manual. Final report prepared for The Clean Washington Center, Seattle, Washington.
- Rynk, R. 1992. On-farm composting handbook (NRAES-54). Cooperative Extension. Ithaca, N.Y.
- Watson, M. E. 2002. Testing compost. ANR-15-03, Ohio State University Fact Sheet.

WEBSITES

- University of Idaho Extension (<http://www.extension.uidaho.edu/idahogardens/gb/comp.htm>)
- Cornell Composting (<http://www.compost.css.cornell.edu>)
- Internet Recycling and Composting Resource Page (<http://www.recycle.cc/resource.htm>)
- Oregon Department of Environmental Quality Composting Program (<http://www.deq.state.or.us/lq/sw/compost/>)
- U.S. Composting Council (<http://compostingcouncil.org>)
- U.S. Environmental Protection Agency (<http://www.epa.gov/epawaste/conserv/rrr/composting/index.htm>)
- Washington State University Puyallup. Composts and Nutrient Management. (<http://www.puyallup.wsu.edu/soilmgmt/Composts.htm>)
- Woods End Laboratories (<http://www.woodsend.org>)

EXAMPLE 1. DETERMINING THE PROPORTIONS OF STRAW AND DAIRY MANURE IN A COMPOST SAMPLE

Mixing straw (moisture content: 20%, C:N ratio: 120, nitrogen content: 0.5%, bulk density: 300 lb/yd³) and dairy manure (moisture content: 80%, C:N ratio: 15, nitrogen content: 2.5%, bulk density: 1397 lb/yd³) based on a desired C:N ratio of 30.

Step 1. Calculate how many pounds of straw per pound of dairy manure are needed using the second equation in Formulas for Two Ingredients on page 3:

$$X = \frac{\%N_y}{\%N_x} \times \frac{R - R_y}{R_x - R} \times \frac{1 - m_y}{1 - m_x} = \frac{2.5}{0.5} \times \frac{30 - 15}{120 - 30} \times \frac{1 - 80/100}{1 - 20/100} = \frac{0.2 \text{ lb straw}}{1 \text{ lb dairy manure}}$$

Where X is the pounds of straw needed for 1 pound of manure,

N_y is the % nitrogen of manure,

N_x is the % nitrogen of straw,

R is the desired C:N ratio of the mixture,

R_y is the C:N ratio of manure,

R_x is the C:N ratio of straw,

m_y is the moisture content of manure,

m_x is the moisture content of straw

Step 2. Calculate how many cubic yards of straw per cubic yard of dairy manure are needed:

$$\begin{aligned} V &= X \times (\text{bulk density of dairy manure} \div \text{bulk density of straw}) \\ &= \frac{0.2 \text{ lb straw}}{1 \text{ lb dairy manure}} \times \left(\frac{1397 \text{ lb dairy manure}}{\text{yd}^3} \div \frac{300 \text{ lb straw}}{\text{yd}^3} \right) \\ &= \frac{0.9 \text{ yd}^3 \text{ straw}}{1 \text{ yd}^3 \text{ dairy manure}} \end{aligned}$$

Where V is the cubic yards of straw needed for 1 cubic yard of manure,

X is the pounds of straw needed for 1 pound of manure

Step 3. Check the moisture content:

$$\begin{aligned} \text{Moisture content} &= \frac{\text{weight of water in straw} + \text{weight of water in dairy manure}}{\text{total weight of straw and dairy manure}} \\ &= \frac{(0.2 \times 20/100) + (1 \times 80/100)}{0.2 + 1} = 70\% \end{aligned}$$

The moisture content is a little higher than the recommended ideal content (50–60%). You can keep the moisture as is or add a little more straw to decrease the moisture content and raise the C:N ratio slightly.

EXAMPLE 2. CALCULATING BULK DENSITY OF MANURE

A 5-gallon bucket weighing 1.5 lb was used as a container of known volume. Three 5-gallon manure samples were weighed as 36 lb, 36.5 lb, and 35.5 lb. What is the bulk density of the manure?

Average weight of the three samples

$$\begin{aligned} &= \frac{(36 - 1.5) + (36.5 - 1.5) + (35.5 - 1.5)}{3} \\ &= 34.5 \text{ lb} \end{aligned}$$

Bulk density of the manure

$$= \frac{\text{Average weight of manure}}{\text{Volume}} = \frac{34.5 \text{ lb}}{5 \text{ gallons}} \times \frac{202 \text{ gallons}}{\text{yd}^3} = \frac{1394 \text{ lb}}{\text{yd}^3}$$

EXAMPLE 3. DETERMINING THE POROSITY OF DAIRY MANURE

A bucket with a 5-gallon line marker was used to measure dairy manure porosity. Manure from a separator was placed into the bucket up to the 5-gallon line. Tap water was then added to fill the 5-gallon volume. The amounts of water added in three repetitions of this process were 10,500, 10,650, and 10,650 ml. What is the porosity?

Step 1. Change the volume unit from ml to gallon

$$10,500 \text{ ml} = 10,500 \text{ ml} \times \frac{0.2642 \text{ gallons}}{1000 \text{ ml}} = 2.7741 \text{ gallons}$$

$$10,650 \text{ ml} = 10,650 \text{ ml} \times \frac{0.2642 \text{ gallons}}{1000 \text{ ml}} = 2.8137 \text{ gallons}$$

Step 2. Calculate porosity

$$\text{Porosity} = \% \text{ voids} = 100 \times \frac{\text{Volume of voids}}{\text{Total sample volume}}$$

$$\text{Porosity for test 1} = 100 \times \frac{2.7741}{5} = 55.5\%$$

$$\text{Porosity for test 2} = 100 \times \frac{2.8137}{5} = 56.3\%$$

$$\text{Porosity for test 3} = 100 \times \frac{2.8137}{5} = 56.3\%$$

$$\text{Average porosity} = \frac{55.5 + 56.3 + 56.3}{3} = 56\%$$

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