Designing the Biochar Pellet

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For fertilizer and soil amendment applications, feedstock, particle size, and formulation can all influence the finished product's performance. Consequently, producing a pellet that meets specific application requirements requires an engineered solution that accounts for multiple inputs and processes to achieve the desired performance outcome.

What Should Determine the Size of a Biochar Pellet?

There may not be a single answer.

Biochar used in fertilizer and soil amendment applications can originate from a wide variety of organic materials including animal manures, crop residues, grasses, bamboo, woody biomass and forest residuals, as well as food waste and digestate. Those starting materials can produce biochar with very different physical and chemical characteristics.

Particle size adds another variable. It can influence how biochar interacts with nutrients, water, and surrounding soil conditions, which may affect nutrient availability, sorption behavior, stability, and how the material behaves after application. For example, in developing biochar pellets for phosphorus capture, smaller pellets performed differently from larger pellets under the conditions tested. [2,5]

Pellet size, then, may be more than a manufacturing specification. It can be part of the product design.

Start With the Material

Biochar feedstocks often reflect the resources available in a particular region. But feedstock is only the beginning. How you process the material also influences the characteristics of the resulting biochar.

Different feedstocks can produce biochars with different surface areas, pore structures, and surface chemistry. Those characteristics can influence how the material behaves and what it may do after it reaches the soil. [1]

This has been demonstrated with biochars produced from very different starting materials. Poultry litter, swine solids, switchgrass, and pine chips, for example, showed differences in carbon mineralization based on biochar source, particle size, and soil type. [6]

A pellet meant primarily as a soil amendment may therefore have different requirements than a biochar-based fertilizer designed to deliver nutrients.

The starting material matters. So does what you ultimately expect the pellet to do.

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What Should Happen After the Pellet Reaches the Soil?

Once a biochar pellet reaches the soil, its physical form is only part of the story.

Biochar can interact with soil, water, nutrients, plant roots, and microorganisms through a range of processes. These interactions vary with the biochar's characteristics and the conditions under which it is applied. [1]

For fertilizer applications, nutrient behavior becomes particularly important. Biochar can serve as a carrier for fertilizer materials, combining the physical characteristics of a pellet with nutrients such as nitrogen, phosphorus, and potassium. Biochar-based fertilizer produced from biogas digestate, for example, has demonstrated sustained release of N, P, and K, with phosphorus exhibiting a particularly strong sustained-release effect. [3]

Particle size can matter here as well. Reducing particle size has been associated with increased short-term phosphorus availability in manure-based digestate biochar. Other work examining

biochar pellets for phosphorus capture found performance differences between smaller and larger pellets. [2, 5]

The pellet must be designed for more than the journey to the field. Its behavior after application matters, too.

So, What Size Is Right?

Smaller isn't necessarily better. Neither is larger.

A smaller pellet provides more exposed surface area relative to its mass and, in some applications, can improve nutrient availability or sorption performance. But very fine material brings many of the handling, dust, and material-loss issues pelletization is intended to address.

Larger pellets can offer advantages in handling and durability, but size can also affect how the material interacts with soil, water, and nutrients. In phosphorus-capture applications, smaller pellets have demonstrated faster phosphorus sorption and higher removal efficiency than larger pellets under field conditions.[5]

The objective isn't necessarily to produce the largest, smallest, or strongest pellet possible. It is to identify a pellet-size range appropriate for the pellet's intended function.

Design for Performance

This is where the idea of a "designer biochar pellet" comes into focus.

What does the pellet need to do?

Does it need to withstand transportation and mechanical application?
Is it carrying N, P, or K?
Is controlled nutrient release the goal?
How quickly should the pellet break down?
How much strength is needed before durability works against the pellet's intended behavior after application?

Those requirements can drive decisions about pellet size, formulation, binder, moisture, and processing conditions rather than the other way around.

Formulation Becomes Part of the Design

Once the job of the pellet has been defined, formulation becomes part of the design.

Maize flour, rice starch, carboxymethyl cellulose (CMC), and commercial starch have all been evaluated as binders in biochar pelletization, producing differences in size distribution, density, attrition resistance, and crushing strength. [4]

There isn't one binder that is right for every biochar or every application. Binder selection is another variable that can change the physical characteristics of the finished pellet.

Pelletization requires a binding mechanism. In some formulations, water alone may provide sufficient particle bonding, while others require additional organic or inorganic binders. Binder-free biochar-based fertilizers with varying moisture content, pellet size, and processing conditions affect properties such as strength and durability. Moisture itself can contribute to particle bonding, while too little or too much can affect the quality of the finished pellet. [3]

So, the formulation question is bigger than which binder to use.

It includes the characteristics of the biochar, the fertilizer or other materials being incorporated, moisture, binder type and concentration, target pellet size, strength requirements, and what needs to happen to the pellet after application.

Conclusion: Testing Before Scale

With biochar, the question isn't simply whether a material *can* be pelletized. It's what kind of pellet the application requires.

Feedstock characteristics, particle size, moisture, binder selection, and formulation interact in material-specific ways. Small-scale testing lets you evaluate those variables together, comparing different formulations against target particle size, strength, durability, and other performance requirements before moving to commercial-scale production.

The objective is not simply to make a pellet. It is to develop the pellet the application performance requires.

About the Author

Elliott J. Woodward, P.E., is Business Manager at Mars Mineral and specializes in process development and scale-up of pelletizing and agglomeration systems.

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