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Unlocking Biochar's Full Potential Through Pelletizing

The functional benefits of biochar pelletization offer agronomic, industrial and environmental advantages.

BY CRAIG VAUGHAN

In the growing movement toward circular bioeconomy solutions, biochar is emerging as more than just a soil amendment. When formed into high-performance pellets, biochar becomes a robust tool for pollution remediation and nutrient delivery, a cost-effective source of carbon for steelmaking, and a sustainable construction material design.

Mars Mineral has seen firsthand how precision pelletizing from milled biochar can transform waste materials into value-added products with wide-reaching commercial and industrial applications.

Shaping Biochar for Real-World Use

Biochar has been championed for its carbon-stable framework, water retention capability and porosity, making it a compelling candidate for environmental and agricultural use. In its raw powdered or crushed form, however, it is often dusty, hard to handle and inconsistently applied. Pelletizing addresses these challenges.

Advantages of Pelletized Biochar

- Densification improves handling, packaging, transportation, storage and application efficiency.
- Mechanical stability ensures product integrity during handling and shipping.
- Consistent pellet size distribution enables reliable application rates in soil or filtration systems.

By tailoring moisture content, pellet size distribution, and binder selection, the pelletizing process optimizes biochar's structural and functional properties for targeted use cases—from field spreading to wastewater treatment to steelmaking.

Mars Mineral's proprietary pelletizing technology is engineered for industrial scalability and precise control over pellet properties. It is also optimized to handle a wide range of biochar feedstocks, including forest waste such as slash, food processing waste and biomass ashes.

Mars' pin mixer acts as a high-speed conditioner, mixing fine materials with moisture and binders to initiate microagglomeration. As a standalone pelletizer, the pin mixer generates round pellets typically in the 0.5–2mm range. When paired with our disc pelletizer, the result is dense, spherical pellets in the 1–4mm range.

This two-step process allows for shorter drying times, more efficient binder usage, higher throughput and greater control over pellet bulk density, strength and porosity.

What the Research Says: Pelletizing Biomass and Biochar

Research by Rambhatla et al. (2024), published in *Resources, Environment and Sustainability*, shows that pyrolysis temperature and hold time within the 400–900 degrees Celsius range have a direct impact on biochar yield, structure and density. In the study, bulk biomass was pyrolyzed in a nitrogen atmosphere under tightly controlled temperature profiles to assess how thermal treatment impacts material performance. Some of the findings were as follows:

- Maximum biochar yield occurs around 400 C, making it ideal for soil and nutrient applications.
- As pyrolysis temperatures increase to 600–900 C, biochar yield declines due to the increasing loss of volatiles, but carbon content, higher heating value and thermal stability increase.
- Biochar produced at 900 C has a highly aromatic carbon framework with lower oxygen and hydrogen content, making it suitable for filtration applications such as the removal of metal or organic contaminants.
- Morphology also shifts: Lower-temperature chars retain structure useful in soil amendments for water retention, while higher-temperature chars develop enhanced performance properties for pollutant adsorption.

The study also demonstrated that increasing pyrolysis temperatures used to convert biomass into biochar increases carbon and ash content and bulk density, and decreases surface area, porosity, hydrophilic functional groups and water adsorption, making the biochar surface more hydrophobic. These thermal effects are key to selecting pyrolysis parameters that align with intended end uses.

In practice, biochar produced under these conditions must be milled into a fine powder before it can be pelletized. Consequently, the binders, binder adjuncts and pelletization equipment settings must be optimized to meet functional pellet specifications for each intended application.

Process Development Considerations

Pelletizing biochar is not a one-size-fits-all process. Each feedstock varies in moisture, volatiles and particle shape, requiring customized process development. Mars Minerals uses lab trials and pilot-scale testing to validate performance before scaling up. Key factors include:

- Moisture content: This is essential for green pellet strength without overburdening drying systems.
- Binder chemistry and loading: Options typically range from water alone to aqueous lignosulfonates, humates and starches, depending on application and sustainability goals.
- Pellet size, size distribution and strength: These characteristics are tuned for the application—smaller and harder for filtration, and larger and weaker for rapid soil dispersion as a soil conditioner.

Through iterative testing, Mars Minerals fine-tunes input ratios, equipment settings and post-processing steps to ensure that biochar pellets meet the demands of agriculture, remediation or material manufacturing.

Enabling the Circular Bioeconomy

Pelletized biochar exemplifies the convergence of carbon management and waste valorization. By transforming residual biomass into engineered pellets, producers can move closer to zero-waste, carbon-neutral manufacturing while generating materials that sequester carbon, purify water and restore soil health. Benefits include:

- Forestry: Biochar pellets support wildfire mitigation, improve water retention, balance soil pH, and enhance microbial activity for long-term regeneration.
- Agriculture: Nutrient efficiency is improved while handling and application challenges are addressed.
- Water purification: Biochar pellets act as sorbents for metals, dyes and other pollutants.
- Construction materials: Thermal and structural performance is improved in composites, bricks and cement.
- Environmental engineering: Attention is attracted for remediation of contaminants from heavy metals to industrial solvents.

One of the most urgent uses is in mitigating per- and polyfluoroalkyl substances (PFAS) in soil and water. With the right feedstock and high-temperature pyrolysis, biochar can be tailored for porosity and surface area to adsorb PFAS. When pelletized, it is easier to deploy in fixed-bed filters or in-situ soil treatments, offering a practical alternative to activated carbon in select applications.

In every case, pelletizing turns waste into value, expanding biochar's potential across multiple industries.

Carbon Sequestration and a Role in Carbon Credit Markets

Biochar stores carbon in a stable form that resists decomposition, making it a credible tool for long-term sequestration. When pelletized, it becomes easier to handle and verify—key requirements for participation in voluntary carbon markets.

Programs like Puro.earth recognize biochar-based credits, opening revenue opportunities for producers. Mars Mineral's pelletizing systems support this market by ensuring consistent product quality and traceability.

Pelletized biochar transforms waste biomass into a durable, marketable carbon sink—advancing both soil health and climate goals.

The Path Forward

As policymakers and markets push for decarbonization and resource recovery, pelletized biochar offers an adaptable, science-backed bridge between waste streams and valuable products. With proven equipment such as the Mars Mineral disc pelletizer and pin mixer, and more than 60 years of experience, stakeholders across the biomass spectrum—from pyrolysis operators to soil amendment producers—can realize the full potential of their carbon-rich materials. However, successful implementation starts with partnership. Companies exploring biochar pelletization should engage in collaborative trials that reduce risk, speed development and deliver fit-for-purpose pellet solutions.

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