

Editorial

WASTE MANAGEMENT IS PIVOTAL IN THE CROSSROAD BETWEEN FOOD AND BIOCHAR PRODUCTION OUTCOMES

Introduction

Increases in farm food waste, like in other parts of our globe, call for long-term sustainable solutions that will help reduce the emergent associated environmental/health risks. Besides, many food waste mitigation efforts largely focus on retail and consumer stages. There remains considerable food waste within the production phase, from growing, harvesting, transportation, to storage/ processing (Srivastava and Tonjes, 2025). However, biochar production appears positioned as a promising problem-solving approach applicable to farm food waste. When integrated with on-farm operations, biochar production can potentially improve farm viability while mitigating food waste challenges. As biomass, organic waste, and agricultural residues remain widely recognized as promising feedstocks for biofuel and energy production, thermo-chemical processes can convert these wastes into valuable energy products such as biochar, eventually becoming a sustainable and environmentally friendly solution (Rasaq et al., 2021).

Biochar and its production

Biochar—a carbon-rich material, is generated by “roasting” organic materials in a “pyrolyzer oven” operating at high temperatures (350-700°C) with limited oxygen, able to remove water and volatile organic compounds. Feedstocks for biochar production can come from diverse sources but need to be of low cost if the final product is to be economically viable (Rasaq et al., 2024). Key biochar production process steps include a) Gathering feedstock to the processing plant; b) Sorting, drying, and grinding (as needed), and c) Feeding into the pyrolyzer. Biochar production, as involving “thermochemical conversion” process (as shown in Figure 1), operates by different process variations, namely: a) Slow pyrolysis; b) Fast pyrolysis; c) Torrefaction; d) Hydrothermal Carbonization (HTC); e) Gasification. HTC is somewhat unique in the above list, as it operates at 180-374°C and 4-22 MPa to produce hydrochar and aqueous-phase products without requiring pre-drying. Torrefaction typically operates at 200-300°C with residence times of 15-60 min. Pyrolysis, carried out at 300-700°C,

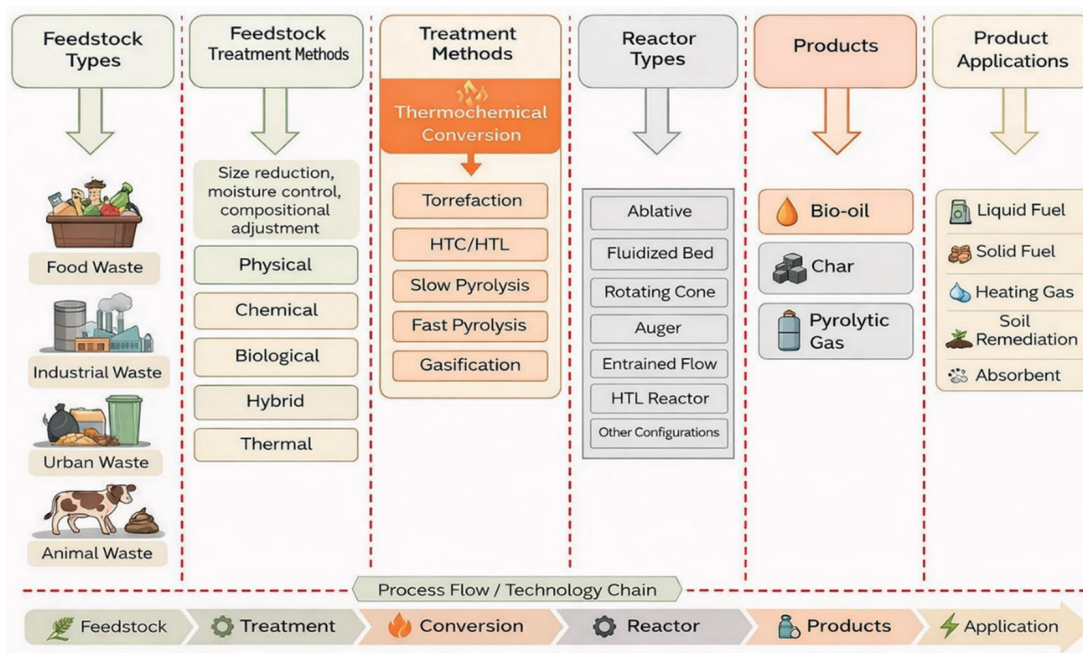


FIGURE 1: Thermochemical conversion pathways for the valorization of diverse waste feedstocks. Feedstock types, pretreatment methods, thermochemical conversion routes, reactor configurations, products, and end-use applications are shown. Red dashed lines separate the main stages of the technology chain. (Modified from Rasaq et al., 2024, Open Access - Creative Commons Attribution (CC BY) license)

produces biochar, bio-oil, and syngas, while gasification operates above 700°C to generate syngas rich in hydrogen and carbon monoxide (Rasaq et al., 2024).

Farm food waste

Farm-level food waste alone accounts for approximately 16.8% of total U.S. food waste, highlighting the critical role producers play in the overall efficiency of the supply chain. By USDA, over one-third of food produced is either lost or wasted before reaching consumers, with a substantial portion at the farm level. For example, food loss/waste in the U.S. is estimated to cost roughly \$218 billion annually, emphasizing the enormous financial impact across production, distribution, and retail (Divert, 2025). Farm food waste can arise for several reasons: a) Crops damaged in the field, rendering them unsaleable; b) Produce rejected due to not meeting retailer specifications (i.e. blemishes, color, or even size); c) Farm food waste caused by surplus, where farmers obtain more crops than can be sold on the market; d) Farm losses from unharvested crops due to labor issues. Most food waste at the farm level is either handled by being left in the field or ploughed back into soil or grazed by animals. As such, it might not be completely wasted, although most of its value is lost to the farmer. At consumer end of food supply chain, massive amounts of (food) waste increasingly taken to landfills /incinerators calls for biochar production even more! When food waste gets dumped at a landfill, it decomposes and releases methane and CO₂ into the atmosphere relatively quickly, before (landfill) been capped and gases captured. Thus, by diverting food waste from landfills, biochar production can reduce overall emissions of undesirable gases to the atmosphere. Further, by removing large quantities of food scraps (from homes, institutions, industry) from landfills, biochar production reduces the space (landfills) occupied, including environmental risks that arise from (landfill) leakage.

Biochar utilization

Biochar-amended soils have been shown to result in enhanced crop yields from vegetable crops like lettuce, and staple crops like maize and wheat. When incorporated into the soil, biochar from food waste can provide essential nutrients to the crops, functioning in the capacity of a slow-release fertilizer as shown in Figure 2, together with other promising attributes such as soil water capacity improvement, microbial community enhancement, and long-term carbon sequestration (Blenis and Hue, 2023). In this context, biochar should improve soil quality, support remediation of contaminated soil(s), and reduce the need for fossil-based soil amendments. If additional products can be created during the biochar production process, the systematic recovery of these valuable materials, products, and energy from food waste should support both environmental protection and economic growth - closely aligning with circular (bio)economy and sustainable development principles.

Some biochar examples tackling US farm food waste There are promising examples in the United States where biochar production via pyrolysis has helped manage problematic agrifood waste. By converting crop residues, husks, orchard pruning, and food scraps into a valuable soil amendment, biochar supports a circular economy, sequesters carbon, and enhances soil health. For instance, in California's Central Valley, biochar production from orchard waste has reduced farm waste, created jobs, and contributed to a growing bioeconomy (AFT, 2020). Applied Carbon, a U.S.-based start-up, has developed an agricultural robot that efficiently converts plant waste into biochar, providing a mobile and scalable solution for on-farm carbon capture and soil fertility enhancement (S Foundation, 2024). Similarly, the non-profit Soil Cycle in Montana employs a community-focused model: food scraps are collected via e-bikes, processed into biochar, and returned to local garden, demonstrating both waste reduction and soil impro-

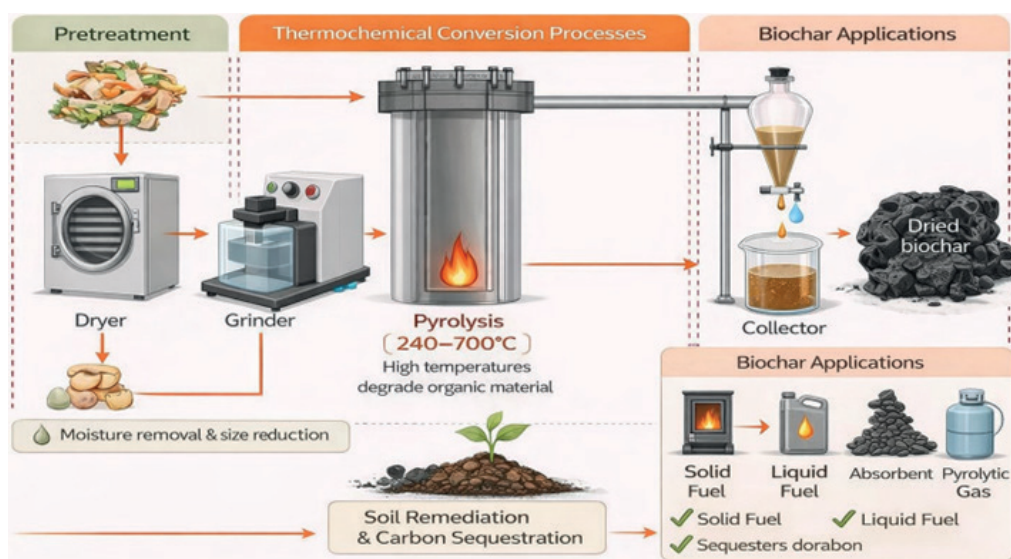


FIGURE 2: Biochar production from food waste via thermochemical conversion, including pretreatment (drying and grinding), pyrolysis (240-700°C), product collection, and applications in fuel, adsorption, and soil remediation (illustration created by Waheed A. Rasaq).

vement at a regional level (National Center for Appropriate Technology). Additionally, the American Farmland Trust has documented the economic and agronomic benefits of biochar production through partnerships with farmers, including almond orchards in California (AFT, 2020). The U.S. Forest Service's Rocky Mountain Research Station (RMRS) also conducts active research on biochar, exploring its applications in soil health, pollution mitigation, and carbon sequestration, often using forest slash as feedstock.

The (above-mentioned) examples reveal situations that demonstrate opportunities of laboratory-scale results translate to large-scale U.S. waste management/soil amendment systems. Furthermore, the diverse nature of food waste, and the challenges associated with biochar production via pyrolysis makes more relevant the need for increased extension outreach efforts to increasingly educate many more US households, foodservice and all relevant (food waste) producing industries. Expanding extension outreach/knowledge base to include agricultural engineering/processing experts specialized in tackling food waste biochar production via pyrolysis will further support the capacities of those tackling environmental health impacts/risks associated with (food waste) disposal/removal.

Challenges and opportunities for biochar from food waste

Despite biochar production's ability to subject organic biomass of water-rich environment to high temperatures/pressures, the food waste still presents distinct limitations (for biochar production application), namely: a) its composition can vary widely; b) it tends to be high in moisture; c) its availability tends to vary over the course of the year; and d) the volume available at one location may not match the size needed for industrial biochar production or for the local biochar market. For instance, U.S. food waste are believed to typically contains higher proportions of processed foods, meats, dairy products, oils, and packaged items compared to laboratory-prepared or model food waste streams (EPA, 2023).

Differences in food waste composition can significantly influence pyrolysis performance, including biochar yield, energy recovery, and emissions behavior. Food waste streams rich in lipids and proteins—such as those commonly found in U.S. households—tend to exhibit higher energy potential during thermal conversion but also introduce operational challenges (Su et al., 2022). Beverage, sauce, and fresh produce emerging from U.S. household disposal fur-

ther elevates the varying moisture content of food waste, which can reduce thermal efficiency and increase pre-treatment energy requirements. One possible approach to handling these challenges could be to incorporate Anaerobic Digestion as a preprocessing step. Besides, some farms that already have digesters for processing manure also utilize some food waste, with generally positive results. The addition of biochar production to the system could result in greater benefits to the farmer and to the community.

Concluding Remarks

Overall, converting agrifood waste into biochar represents a promising strategy to simultaneously address organic waste streams, soil degradation, and renewable energy needs. The development of effective thermal treatment strategies, with recommendations for improving biochar quality, highlights the potential of thermochemical conversion as a sustainable, circular solution to the food waste challenge in the US.

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