Biochar derived from pyrolysis of common agricultural waste feedstocks and co-pyrolysis with low-density polyethylene mulch film

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The increase in global food production to meet the demands of a growing population will lead to generation of more wastes in the agricultural sector. However, agricultural wastes can be valuable materials because they are generated in large quantities all over the world, and contain a variety of components that can be converted into value-added products. These wastes include dairy manure, crop residues, and other solid materials such as cardboard and wooden pallets. Plastic agricultural mulch films (AMFs) are also used in many regions to control soil moisture and weed growth for high-value crops such as tomatoes and peppers, but these materials present additional challenges because current waste management techniques are generally limited to landfilling and incineration, both leading to an increase in greenhouse gas emissions (Zhang et al., 2019). However, alternative methods such as pyrolysis can present more sustainable pathways by transforming mixed wastes from the agricultural sector into value-added products such as biochar, bio-oil and syngas. Limited published literature has focused on biochar derived from co-pyrolysis of agricultural wastes with plastic wastes; instead, most prior work is based on fast co-pyrolysis of these materials, which favors bio-oil and syngas production with reduced biochar yield (Dorado et al., 2015). Biochar has considerable potential for enhancing plant growth by improving soil quality and reducing contamination of surface and ground water (Ro et al., 2014). In this study, we are therefore interested in the characteristics and potential applications of biochar generated from pyrolysis of agricultural solid wastes and co-pyrolysis of these wastes with AMFs.

We first investigated the properties of biochar derived from common agricultural wastes materials, including tree and brush waste represented as commercially procured wood pellets (WP), pallet wood (PW) and hammer milled boxboard (HB). All materials were converted in a high temperature furnace (Ceralink 1712GS FL) under nitrogen atmosphere at two temperatures (500 and 800 °C), with a fixed ramp rate of 10ºC/min and hold time of 60 min. The biochar materials thus produced were characterized by in-house pH measurements and surface area measurements using a Quantachrome BET system. Additional characterization data were provided by Control Laboratories (Watsonville, CA, USA), following a protocol recommended by the International Biochar Initiative (IBI). The results show that all three target feedstock materials produced biochar that is suitable for soil amendment, based on high organic carbon content that exceeds 65% in all cases (Figure 1), hydrogen-to-carbon ratio (H:C) less than 0.7 (indicating carbon recalcitrance; IBI, 2015), and very low or non-detectable concentrations of potential contaminants such as mercury, lead and cadmium. These initial results are now being extended to include a third pyrolysis condition of 650ºC, enabling us to develop empirical relationships for key biochar properties (yield, organic carbon, H:C, surface area, etc.) as functions of processing temperature. These results will be included in the final paper.

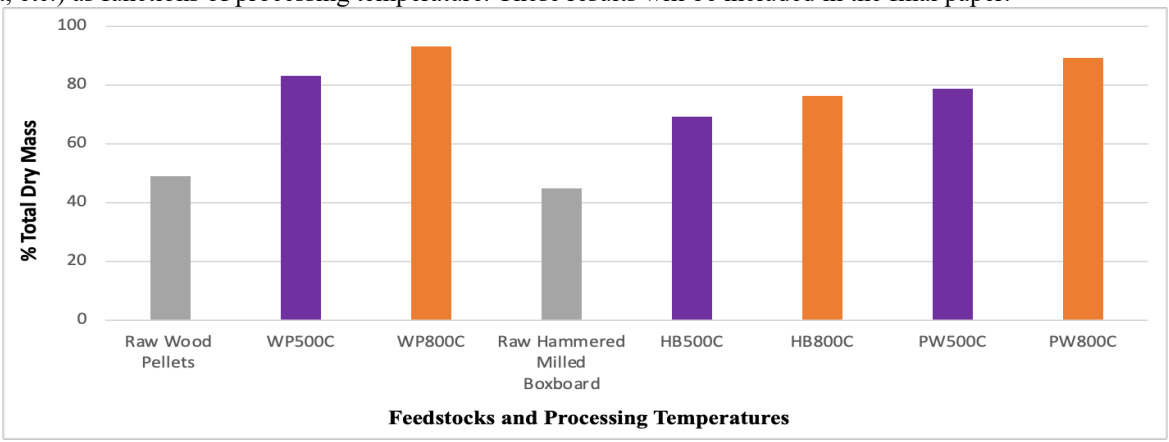

Figure 1. Organic carbon content (% total dry mass) of wood pellets (WP), hammer milled boxboard (HB), and pallet wood (PW) and associated biochar produced at 500 and 800 °C. Note: Raw pallet wood feedstock was not available for analysis.

We furthered assessed the presence of low-density polyethylene (LDPE) agricultural mulch films on properties of biochar derived from wood pellet feedstock at two temperatures (500 and 800°C) and at three different wood-to-LDPE mass blend ratios (100:0, 95:5 & 75:25). These blend ratios were based upon data provided by farms in our region, which indicate that the total amount of biomass wastes produced far exceeds the amount of LDPE film used annually. Therefore, a co-pyrolysis process could reasonably involve a small amount of plastic mixed with a much larger amount of biomass material. Our results indicate that the presence of the LDPE film material generally had small effects on the biochar quality. The biochar materials produced by co-pyrolysis had high organic carbon content (C_{org}), and hydrogen-to-carbon (H:C) ratio less than 0.7 indicating long-term carbon stability (IBI, 2015), in both cases comparable to the biomass-only results (Figure 1). Assessments of soil enhancement properties and heavy metals present in the feedstocks were also evaluated, and found to be comparable to biochar produced with LPDE material included (Table 2). However, two biochar parameters that showed somewhat elevated levels due to the presence of LDPE were total ash and pH. We are now conducting further analysis (to be included in the final paper) to determine if higher ash and pH of some of the co-pyrolysis derived biochar products would preclude their use in soil amendment applications. Additional measurements are underway to assess the presence of other potential toxicants, such as dioxin and polycyclic aromatic hydrocarbons (PAH), that could also limit the use of co-pyrolysis derived biochar in agricultural applications.

Table 1. International Biochar Initiative standard testing results on biochar derived from wood pellets (WP) and wood/LDPE film (FM) blends at different processing temperatures.

			Nutrients (mg/kg)			***Physical Properties***			
Feedstock	**Temp (°C)**	**Total volatile matter (%/dw)**	**Org-N**	**P**	**K**	**Bulk density (kg/m^3)**	**Total ash (%)**	**pH**	**Surface area (m^2/g dry)**
Raw WP	-	80.2	1,784	99.0	1,361	346.0	0.6	12.37	154
WP	500	20.7	4,040	69.0	2,518	233.9	1.4	4.40	207
WP	800	6.0	7,615	10.0	2,166	249.9	1.6	5.93	118
WPFM (95/5)	500	17.7	3,933	40.0	2,252	213.0	1.9	11.10	237
WPFM (95/5)	800	3.0	7,383	2.0	1,816	233.9	2.3	7.22	133
WPFM (75/25)	500	18.3	3,631	82.0	2,413	289.9	3.2	10.50	238
WPFM (75/25)	800	3.8	7,370	24.0	1,675	262.7	3.6	8.04	131

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