

Title: Application of char derived from co-pyrolyzed Eucalyptus wood and plastic waste as solid fuel in a forced-draft cooking stove

ABSTRACT

Rising population coupled with robust economies has increased the reliance on plastic and non-renewable fossil fuels, unreliable and unsustainable. Plastics, despite their numerous benefits, have always posed a problem of waste disposal pertaining to economic and technological constraints. Managing large amount of plastic waste made of film [esp., Low density polyethylene] and foam [esp., Polystyrene] in particular, have not been of preference to recyclers considering their higher processing costs and other economic viabilities, is becoming a serious concern for the growing civilisation and environment. These plastic wastes have enormous energy potential. On the other hand, the fourth largest source of energy in the world is biomass. Approximately three billion people rely on traditional, less efficient cooking stoves and firewood like raw biomass to meet their household energy demand. Along with being not an ideal energy carrier, biomass faces great barriers originating from its inherent bulkiness, fibrous, high moisture content, and low-energy-density nature, leading to key issues including high transport cost, low calorific value and poor grindability for its direct utilization as a fuel. The inherent advantages of co-pyrolysis in recovering value added by-products from plastic waste and biomass makes it an economically and environmentally viable management technique. In the current research, the prospects of the char derived from the co-pyrolysis of Eucalyptus wood (EW) and plastic wastes (Waste Polystyrene (WPS), Waste Low density polyethylene (WLDPE)) as an energy source in indigenously designed forced draft cooking stove are explored. The study shown that energy dense char recovered from pyrolysis has enhanced phytochemical and thermal properties such as grindability, hydrophobicity, high heat value, and energy density compared to its raw feedstock, making it a superior solid fuel. Pyrolysis temperature and feedstock proportions were shown to have a substantial impact on the physicochemical and thermal properties of the chars. The inhibitory effect of the overlaying plastic coating resulted in chars with higher yield and calorific values, as well as lower fixed carbon contents and fuel ratios, at low pyrolysis temperatures. However, at temperatures above the degradation of plastics, the synergistic effect between the feeds during co-pyrolysis has resulted in the formation of a dense, carbonaceous, and low volatile content with high fixed carbon content char suitable for application as household fuel. Lower O/C and H/C ratios in char imply a high degree of carbonization during the pyrolysis process, as well as low energy, water vapour, less smoke after combustion, and longer duration for overall combustion efficiency. For usage as a domestic fuel, the optimal parameters were determined to be 500°C

and 120 minutes for both types of char. The char was densified with molasses as a binder with proportion varying from 10% to 30%, to improve the energy density and make it easier to use, store, and transport. A considerable rise in pellet mass density with an increase in molasses concentration in of char can be attributed to the increase in energy density by 21.5% – 30.75% for both types of pellets. The thermogravimetric analysis showed that molasses pellets burned and combusted more easily in a moderate process, and that adding molasses binder (30%) during pelletization is an effective technique to use char as solid fuel. The pellets were assessed as solid fuel in an indigenously designed forced draft cooking stove. The performance of a forced draft cooking stove using both the types of pellets as solid fuel was evaluated using the Water Boiling Test (WBT). The thermal efficiency of the forced draft cooking stove ranged from 43.6 to 51.8% for WLDPE–EW pellets, and 41.7 to 50.2% for WPS–EW pellets at different phases of analysis. On both cold and hot starts, WLDPE–EW pellets had the quickest boiling times of 15.3 minutes and 13.2 minutes, respectively. The indoor air pollution was relatively much lower than other improved cooking stoves using biomass as fuel. In the current pyrolysis setup, the cost of producing WLDPE-EW and WPS-EW char was found to be ₹99.46 and ₹110.57 per kg, respectively. If the other by-products are recovered, the price of WLDPE–EW and WPS–EW char can be lowered by 70.81 % and 66.51%, respectively, resulting in a cost benefit of 41.77% and 40.93% in pellet pricing. Moreover, the cooking expenses per person per day to use WLDPE–EW and WPS–EW pellets as fuel can be reduced by 42.52% and 40.21% respectively if the by-products are valorised. However, a potential switch from biomass combustion to electricity for pyrolysis process energy demands and the recovery of bio-oil and syngas can significantly increase the environmental and economic efficacy of the entire char production, densification and use as a solid fuel in indigenously designed forced draft cooking stove process. So, the recovery of char from co-pyrolysis and its application as a solid fuel in cooking stove could be sustainable techniques of plastic waste management, while solving the challenges associated with household energy constraints.

Keywords: *Co-pyrolysis, Plastic waste, Char, Densification, Solid fuel, and Forced draft cooking stove.*