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Progressing from Terra Preta de Índios to the Whole World

The production of biochar and by-products

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Introduction

Biomass is heated in the absence of air or oxygen to decompose or devolatilise the biomass into solid char, liquid as bio-oil, tar or pyroligneous liquor and gas. Three products are always produced. Product yields depend on biomass, vapour and solids residence time, and temperature. There are several modes of pyrolysis.

Fast pyrolysis produces up to 75wt.% liquid with some byproduct char and gas. A wide variety of reactors have been developed including fluid beds and circulating fluid beds.

Intermediate pyrolysis produces approximately equal proportions of solid, aqueous liquid, organic liquid and gas. It is a slower method typically carried out in auger or screw reactors or rotary kilns that are particularly suitable for heterogeneous wastes in terms of composition and/or size.

Slow pyrolysis maximises the production of charcoal. It is carried out in continuous or batch reactors.

Torrefaction is low temperature slow pyrolysis to enhance properties including water, heating value and friability.

Table 1. Types of pyrolysis, conditions and typical product distribution

Mode	Conditions *Wt % products*	*Liquid*	*Char*	*Gas*
Fast	~ 500ºC; very short hot vapour residence time (RT) ~1 s; short solids RT	**75%**	12%	13%
Intermediate	~ 500ºC; short HVRT ~10-30 s; moderate solids RT	50% in 2 phases	25%	25%
Slow	~ 400ºC; long HVRT; very long solids RT	30%	**35%**	35%
Torrefaction	~ 300ºC; long HVRT; long solids RT	Vapours	**80%** solid	20% vapours
Gasification	~ 800-900ºC; short HVRT; short solids RT	1-5%	0% (all burned)	**95-99%**

Results and Discussions

Charcoal yields are shown in Figure 1. Products that are not charcoal, i.e. gases, liquids and vapours, must be managed effectively through safe disposal or recovery of valuable products.

Fast pyrolysis

Fast pyrolysis aims to maximise liquids. This is achieved with very high heating rates usually requiring very small particle sizes of generally <3mm in size and < 10% moisture. Total liquid yields are up to 75 wt.% on dry biomass feed. The charcoal forms about 10-15 wt.% of the products. It retains all the alkali metals. It is often used to provide process heat for which about 50-75 wt.% of the char is required. Some processes consume all the char and some use part of the charcoal for process heat. Char is captured in enclosed vessels and can be handled in enclosed vessels.

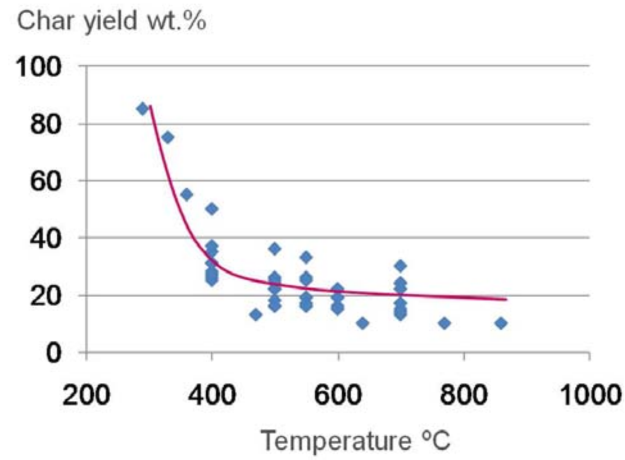

Figure 1. Charcoal yields vs temperature

Fast pyrolysis char is pyrophoric i.e. it spontaneously ignites when fresh; it has a small particle size – from maximum 3 mm from fluid beds down to fine dust; and may be used within the process for heat or exported.

Intermediate pyrolysis

Intermediate pyrolysis processes include rotary kiln, screw, auger, moving bed and fixed bed reactors. Intermediate pyrolysis can process more difficult materials with handling and/or feeding and/or transport problems. The charcoal forms about 25 wt.% of the products. It retains all the alkali metals. Due to the mechanical and abrasive action of the reactor, the charcoal will tend to be small particle size. The liquid is 2 phases – aqueous and organic.

Slow pyrolysis

Processes include batch kilns and retorts and continuous retorts e.g. Lambiotte and Lurgi. Feed size and shape is important. Heating can be direct (air addition) or indirect. Charcoal is mostly lump with smaller particles and some dust. Gases, vapours and liquids are seldom collected or processed. Exceptions include Usine Lambiotte inn France (now shut down) and proFagus (Chemviron/Degussa) in Germany (still operating).

Table 2 summarises the performance and economics of the Usine Lambiotte plant in France during 2000/2001. This shows the significance of the chemicals recovery to the viability of the operation and the management of all the outputs.

Table 2. Economics of Usine Lambiotte slow pyrolysis operation showing significance of chemicals recovery.

	t/year	€/t	k€/y	%
Charcoal	25,000	*100	2,500	31.5
Total pyroligneous liquid	40,000			
Water	30,000			
Organics	10,000			
Acids and alcohols	3,830	452	1,732	
Oils	310	1,258	390	
Fine chemicals	56	49,732	2,785	35.1
Fuel	5,804	90	522	
Total organics	10,000	543	5,429	68.5
Total income			7,929	

Torrefaction

This is very low temperature pyrolysis. It enhances the properties of the biomass by removing water, reducing hemicellulose, Improving heating value, Improving the friability of the product for subsequent processing e.g. Grinding. Vapours can either be burned to provide some process heat or waste disposal; or collected to yield potentially valuable chemicals, but some disposal will always be needed.

The role of torrefied biomass for carbon sequestration is not well understood: questions arise concerning unknown life and effect in soil.

Questions

What is the maximum level of volatiles in charcoal compatible with acceptable health and safety and bio-toxicity levels? This will tend to maximise charcoal yields.

What is the minimum pyrolysis temperature to give a relatively permanent carbon sequestration effect? This will also tend to maximise charcoal yields.

What is the best method of applying charcoal to land?

What chemicals can be economically recovered from co-products?

What is the optimum waste disposal solution?

Conclusions and Recommendations

Conclusions

- Pyrolysis is very flexible in the process and products.
- Chemicals can be produced from the liquids with considerable economic potential.
- Non-products are wastes and must be effectively disposed of.

Recommendations for char production

- Technologies needs to be improved to increase char quality and char yield.
- Technologies need to satisfy emissions and health and safety requirements.
- Technologies need to be optimised for valuable products and disposal of wastes.