



Gasification of non-woody biomass: A literature review

Elita R. Widjaya^{a,b}, Guangnan Chen^{a,*}, Les Bowtell^a, Catherine Hills^a

^a Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD 4350, Australia

^b Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture, Rep of Indonesia, Jl. Ragunan 29 Pasar Minggu, Jakarta 12540 Indonesia

ARTICLE INFO

Keywords:

Non-woody
Biomass
Densification
Gasification
Co-gasification

ABSTRACT

Non-woody biomass, having a lower lignin content than woody materials, is a common waste material found in agricultural processing plants and fields. Non-woody biomass is often bulky and has a comparatively low energy content. However, non-woody materials sourced from agricultural waste are abundant and cheap. Experimental studies into gasification of non-woody biomass have been conducted by various researchers. This paper reviews feedstock characteristics, pre-treatments, gasification methods, and future directions of this technology. Due to the heterogeneous nature of non-woody biomass, it is critical to apply suitable pre-treatments prior to gasification. Combining non-woody biomass with a small percentage of high grade carbon sourced from biochar or coal into fuel pellets for co-gasification has the potential to improve fuel quality. Synergistic effects of non-woody biomass-coal/charcoal co-gasification can also reduce tar formation and increase the occurrence of mineral based catalytic reactions. Factors influencing these effects are often complex and require further investigation. 15–20% of the energy content of fuel pellets may be needed to power the biomass pre-treatment process. The gasification of pelletised non-woody waste provides an attractive alternative fuel source to achieve agricultural energy self-sufficiency and off-grid operation.

1. Introduction

Non-woody biomass has a lower lignin content than woody biomass sources and may often be categorised as waste. This type of biomass may come from a wide range of agricultural processes, animal wastes and herbaceous plants. Common examples of non-woody biomass from agricultural processing plants include cotton gin trash (CGT), palm oil waste, sugarcane bagasse and animal paunch waste. Typical agricultural field wastes are paddy husks, straw, grasses, crop stubble and trash.

Non-woody agricultural waste is abundant, readily available and inexpensive e.g. one hectare of a cotton grown in Australia will typically produce 1.6 t of cotton lint and 2.5 t of cotton-seed. At the same time, it will also generate about 2 t of straw and 0.4 t of cotton gin waste [1]. On average, Australia produces some 25 million tonnes of wheat and 8 million tonnes of barley each year, with a significant amount of non-woody biomass in the form of straw and chaff produced. Typical straw to grain ratios for wheat and barley are 1:1 and 0.7:1 respectively.

The disposal of agricultural waste often encounters significant environmental and associated health issues. Currently in Australia, cotton stalk waste are usually returned to the field to increase the soil organic matter. A common practice of managing cotton gin waste is the use of

composting. However, this option often faces the problems of low market demand and also possible pathogen contamination concerns from the composted product [1].

Recycling the gin waste to generate energy is another option, e.g. the cotton gin waste can be recycled into an energy source to meet the energy demand of the ginning plants. An added bonus of this approach is that it does not incur any additional fuel transportation costs. Waste to energy practices have been used successfully in other industries such as sugarcane and palm oil production. Bagasse and oil palm shell are recycled as the primary fuel for combined heat and power systems. However, the current utilization of waste in combustion systems often only achieves low efficiency energy conversion. Non-woody biomass has the characteristics of being a low density, low quality solid fuel, with varying properties, improving the energy conversion efficiency of the non-woody biomass remains a significant challenge.

The process of energy conversion can be divided into biological and thermochemical processes. Biological processes that include fermentation into ethanol and anaerobic digestion into methane gas face the challenge of some feedstock having a low lignocellulosic conversion rate. Thermochemical processes can be categorized into pyrolysis, combustion and gasification. Pyrolysis which produces bio-oil has limitations in oil utilization and difficulty in the downstream oil processing. Biomass combustion, which usually generates a considerable

* Corresponding author.

E-mail address: Guangnan.Chen@usq.edu.au (G. Chen).

amount of heat and power for the processing industry, has low energy conversion efficiency, high gaseous and particulate pollution, and has to compete with established coal based technologies. Another thermochemical process is gasification. It converts biomass through a high temperature limited oxidation pyrolysis-like process into a gaseous mixture, producing a small quantity of char and condensable compounds. This method is often considered the most efficient way of converting lignocellulose material into gas based energy, with typical conversion efficiencies of higher than 50% [2]. Gasification has been intensively studied for a wide range of biomass materials. The methods of gasification can be further categorised into two approaches, firstly by improving or selecting the optimal design of gasifier, and secondly by selecting or upgrading the fuel so that it is compatible with the reactor.

Compared with woody biomass, there is currently a lower utilization of energy production from non-woody sources. This is because non-woody material has a lower energy content and inconsistent particle size, density and specific fuel content. To allow an effective gasification operation, the main considerations for use of non-woody biomass are:

- Characterisation of the feedstock properties
- Pre-treatment of the feedstock
- Gasification process parameters and constraints.

This paper reviews the potential applications and challenges of the use of non-woody biomass for gasification. The future direction of the non-woody gasification will also be discussed. In off-grid areas of rural agriculture such as are regularly found in developing countries, the energy needs of agricultural processing, household power and waste management are often high.

2. Non-woody biomass properties as solid fuel

Solid fuel compositions are typically characterised by proximate and ultimate analyses. Proximate analysis characterises the fuel in terms of fixed carbon, moisture, ash and volatile matter. Ultimate analysis indicates levels of the main chemical elements (C, H, O, N, S) from which thermochemical reactions take place. During these thermochemical

processes, the mineral contents are converted into ash, which is a generally inert material that reduces the effective energy value of a feedstock. Due to higher ash and tar contents, the non-woody biomass gasification process faces technical issues of ash sintering, tar collection and bed bridging [3,4].

Table 1 shows the fuel properties of non-woody biomass in comparison with charcoal (coal & bio-char) and woody biomass. The higher carbon content in solid fuel leads to higher energy content. In contrast, higher moisture and ash in non-woody biomass would decrease the energy content. However, the carbon component is not the only factor influencing gasification. The elements of hydrogen and oxygen from the moisture and oxidants in the gasification process will generally also react to produce hydrogen, methane and CO gas components in the resulting syngas composition. An additional issue with non-woody biomasses is that they generally have low densities, particularly for sources originating from grasses or herbaceous plants. During gasification this can cause difficulties in handling, particularly in regards to control of the fuel flow rate.

The mineral materials found in biomass mainly comprise alkali (potassium, sodium), alkaline earth (calcium, magnesium) and other minerals such as Fe, Si, Al, Cl and P. These materials can potentially form ash during the thermochemical conversion process. Some alkali and alkaline earth minerals may act as a catalyst in the gasification process. However, these minerals may also react with silica to form alkali silicate, which can cause agglomeration and bridging in the gasifier or combustor bed [5,6] and subsequently affecting gas production.

3. Pre-treatment

The objective of pretreatment is to create biomass that is suitable as a feedstock for gasification systems. Because of a wide range of properties of non-woody biomass, the pre-treatment system can become a critical aspect of minimizing failure in the gasification process. The pre-treatment of feedstock includes one or a combined process of size reduction, drying and densification.

Table 1
Proximate and ultimate analyses of feedstock.

Feedstock	Proximate (% as received))				Ultimate (% ash free)					High Heating value (MJ/kg)	Density (kg/m ³)	Reference
	FC	VM	M	Ash	C	H	O	N	S			
<i>Non Woody</i>												
Cotton gin waste	20.8	68.7	11.8	10.5	45.14	4.93	40.43	1.16	0.29	16.6	390	Samy [9]
Sugar cane bagasse	31	65	9.4	3.6	49.4	6.3	43.9	0.3	0.07	18.9	68	Jordan and Akay [31]
Oil palm empty fruit bunch	8.79	82.58	5.18	3.45	46.62	6.45	45.66	1.21	0.035	17.02	1422	Mohammed et al. [32]
Switchgrass	16.8	76.9	6.0	6.3	47.9	6.2	45.0	0.8	0.1	19.6	115.4	Masnadi et al. [58] Mani et al. [62]
Beef cattle manure	11.15	59.05	13.08	29.8	35.4	5.04	27.58	1.79	0.4	15.93	NA	Maglinao Jr et al. [29]
Rice straw ^a	17.25	69.33	NA	13.42	41.78	4.63	36.57	0.7	0.08	16.28	75	Jenkins and Ebeling [63]
Corncoobs ^a	18.54	80.10	NA	1.36	46.58	5.87	45.46	0.93	0.16	18.77	282	Jenkins and Ebeling [63]
Rice hulls ^a	16.67	65.47	NA	17.86	40.96	4.3	35.86	0.4	0.02	16.14	70–145	Jenkins and Ebeling [63]
<i>Woody</i>												
Sawdust ^a	16.27	82.45	NA	1.28	50.26	6.14	42.2	0.07	0.05	20.47	210	Lapuerta et al. [36]
Macadamia shells ^a	23.68	75.92	NA	0.40	54.41	4.99	39.69	0.36	0.01	21.01	680	Jenkins and Ebeling [63]
Coconut shells ^a	21.38	77.82	NA	0.8	49.62	7.31	42.75	0.22	0.10	20.8	NA	Iqbaldin et al. [64]
Redwood ^a	19.92	79.72	NA	0.36	50.64	5.98	42.88	0.05	0.03	20.72	481	Jenkins and Ebeling [63]
<i>Coal (examples)</i>												
Lignite	27.8	24.9	36.9	10.4	71.0	4.3	23.2	1.1	0.4	26.7	641–865	Higman and van der Burgt [65]
Sub-bituminous	43.6	34.7	10.5	11.2	76.4	5.6	14.9	1.7	1.4	31.8	650–900	
Bituminous	54.9	35.6	5.3	4.2	82.8	5.1	10.1	1.4	0.6	36.1	673–913	
Anthracite	81.8	7.7	4.5	6	91.8	3.6	2.5	1.4	0.7	36.2	800–929	
<i>Bio-char</i>												
Wood charcoal	67.5	18.7	6.1	7.7	77	4.2	11.5	0.3	0.6	30.3	200–400	Rasul [66]
Coconut shells charcoal ^a	76.32	10.6	NA	13.08	NA	NA	NA	NA	NA	30.75	450–600	Mozammel et al. [67]

^a Moisture free (dry fuel).

Download English Version:

<https://daneshyari.com/en/article/8111376>

Download Persian Version:

<https://daneshyari.com/article/8111376>

[Daneshyari.com](https://daneshyari.com)