Organic Waste Feedstocks to Energy

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Abstract: Waste-to-energy (WTE) technologies convert waste matter into various forms of fuel that can be used to supply energy**.** Waste feedstocks can include municipal solid waste (MSW); forest and wood industry wastes including bark, chips, sawdust, hardboard dust, mud from paper industry and raw cork; agricultural waste, such as crop silage and livestock manure; industrial waste from coal mining, lumber mills, or other facilities; and even the gases that are naturally produced within landfills. There are four major methods for conversion of organic wastes to synthetic fuels: (1) hydrogenation, (2) pyrolysis, (3) gasification, and (4) bioconversion. Biomass thermo-chemical conversion technologies such as pyrolysis and gasification are certainly not the most important options at present; combustion is responsible for over 97% of the world's bio-energy production. Some processes such as pyrolysis, gasification, anaerobic digestion and alcohol production have widely been applied to biomass in order to obtain its energy content.
[Namık Ak. **Organic Waste Feedstocks to Energy**. *Life Sci J* 2013;10(7s):233-241] (ISSN:1097-8135). http://www.lifesciencesite.com. 36

Keywords: Waste feedstock; Energy; Conversion; Waste management

1. Introduction

All human and industrial processes produce wastes, that is, normally unused and undesirable products of a specific process. Waste-to-energy (WTE) technologies convert waste matter into various forms of fuel that can be used to supply energy. Waste feedstocks can include municipal solid waste (MSW); forest and wood industry wastes including bark, chips, sawdust, hardboard dust, mud from paper industry and raw cork; agricultural waste, such as crop silage and livestock manure; industrial waste from coal mining, lumber mills, or other facilities; and even the gases that are naturally produced within landfills. Energy can be derived from waste that has been treated and pressed into solid fuel, waste that has been converted into biogas or syngas, or heat and steam from waste that has been incinerated. Fig. 1 shows main waste to energy technologies.

The WTE has traditionally referred to the practice of incineration of garbage. Today, a new generation of waste-to-energy technologies is emerging which hold the potential to create renewable energy from waste matter, including municipal solid waste, industrial waste, agricultural waste, and waste by products. The main categories of waste-to-energy technologies are physical technologies, thermal technologies and biological technologies.

Physical WTE technologies mechanically process waste to produce forms more suitable for use as fuel, producing refuse-derived fuel (RDF) or solid recovered fuel (SRF). RDF consists largely of organic materials taken from solid waste streams, such as plastics and biodegradable waste. The municipal waste is first processed to remove glass, metals, and other materials that are not combustible. Autoclaving kills viruses and other potential pathogens, and it also causes plastics to soften and flatten, paper and other fibrous material to disintegrate, and bottles and metal objects to be cleaned of labels. This process reduces the volume of the waste by up to 60%, and the residual material can then be compressed into pellets or bricks and sold as solid fuel. Burning RDF is more clean and efficient than incinerating MSW or other solid waste directly, but the processing add to costs.

Direct combustion is the old way of using biomass. Biomass thermo-chemical conversion technologies such as pyrolysis and gasification are certainly not the most important options at present; combustion is responsible for over 97% of the world's bio-energy production.

Some processes such as combustion, pyrolysis, gasification, anaerobic digestion and alcohol production have widely been applied to biomass in order to obtain its energy content. The oldest of all fuels, wood (or biomass), and the old original fuel of the industrial revolution, coal, are key to this move to a new mission. Technical issues that can lead to doubt about of biomass cofiring with coal are being resolved through testing and experience (Demirbas, 2004a).

Fig. 2 shows that MSW after pretreatment is fed to the boiler of suitable choice where in high pressure steam is used to produce power through a steam turbine. Proper air pollution control measures are taken and ash from the boiler is dumped in the nearby landfill. The choice and types of boilers suitable are described below.

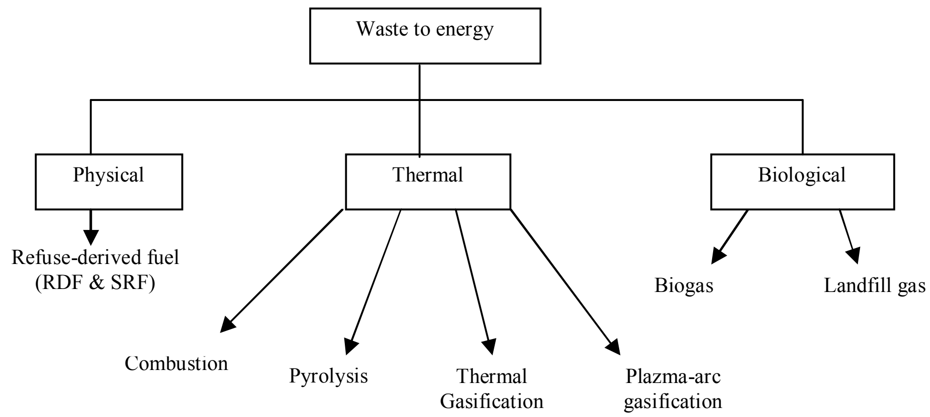

Fig. 1. Main waste to energy (WTE) technologies.

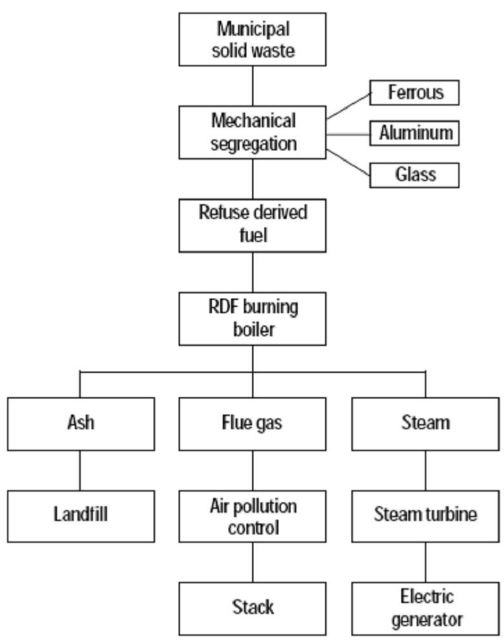

Fig. 2. General flow diagram of an MSW power plant based on incineration technology.

2. Waste classification

There are four major methods for conversion of organic wastes to synthetic fuels: (1) hydrogenation, (2) pyrolysis, (3) gasification, and (4) bioconversion. The first three have been advanced to the pilot-plant stage, while the fourth has been the subject of only minor research effort, but is a long term possibility. Typical solid wastes include wood material, pulp and paper industry residues, agricultural residues, organic municipal material, sewage, manure, and food processing by-products. Biomass is considered one of the main renewable energy resources of the future due to its large potential, economic viability and various social and environmental benefits. It was estimated that by 2050 biomass could provide nearly 38% of the world's direct fuel use and 17% of the world's electricity (Demirbas, 2000). If biomass is produced more efficiently and used with modern conversion technologies, it can supply a considerable range and diversity of fuels at small and large scales. Municipal solid waste (MSW) is defined as waste durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes from residential, commercial, and industrial sources.

Generation refers to the amount of material that enters the waste stream before recovery, composting, or combustion. Recovery refers to materials removed from the waste stream for the purpose of recycling and/or composting. The energy content of MSW in the US is typically from 10.5 to 11.5 MJ/kg. The generation and recovery of MSW varies dramatically from country to country and deserves special mention. For example, recent estimates indicate MSW generation in the UK of about 30 million tons of which 90% is landfilled. In comparison, Sweden landfilled only 34% of their MSW generation (Ekmann et al., 1998).

There are various options available to convert solid waste to energy (WTE). Mainly, the following types of technologies are available: (1) sanitary landfill, (2) incineration, (3) pyrolysis, (4) gasification, (5) anaerobic digestion, and (6) other types. Sanitary landfill is the scientific dumping of municipal solid waste due to which the maturity of the waste material is achieved faster and hence gas collection starts even during the landfill procedure. Incineration technology is the controlled combustion of waste with the recovery of heat, to produce steam that in turn produces power through steam turbines. A gasification technology involves pyrolysis under limited air in the first stage, followed by higher temperature reactions of the pyrolysis products to generate low molecular weight gases with calorific value of 1000–1200 kcal/nm^3. These gases could be used in internal combustion engines for direct power generation or in boilers for steam generation to produce power. In biomethanation, the putrescible fraction of waste is digested anaerobically, in specially designed digesters. Under this active bacterial activity, the digested pulp produces the combustible gas methane and inert gas carbon dioxide. The remaining digestate is a good quality soil conditioner. Other technologies available are pelletization, pyro-plasma, and flash pyrolysis. All these technologies have merits and demerits (Kumar, 2000).

General classification of wastes is difficult. Some of the most common sources of wastes are as follows. These wastes can be classified into (1) Domestic wastes, (2) Commercial wastes, (3) Ashes, (4) Animal wastes, (5) Biomedical wastes, (6) Construction wastes (7) Industrial Solid Wastes, (8) Sewer, (9) Biodegradable wastes, (10) Non-biodegradable wastes, and (11) Hazardous wastes.

Domestic wastes include the wastes generated in houses. It includes paper, plastic, glass, ceramics, polythene, textiles, vegetable waste, etc. Commercial wastes include the waste generated in commercial establishments like shops, printers, offices, godowns, etc. It includes packing materials, spoiled goods, vegetable and meat remnants, polythene, printer paper, etc. Ashes come from the burning of solid fossil fuels like coal, wood and coke. Many houses and road side eateries still use these fuels. Open burning of wastes also generates ashes. Animal wastes are generated from the hospitals and include expired drugs, plastic syringes, surgical dressings, etc. They can be very infectious Biomedical wastes are generated from the hospitals and include expired drugs, plastic syringes, surgical dressings, etc. They can be very infectious. Construction wastes generate garbage like metal rods, bricks, cement, concrete, roofing materials, etc. This type of wastes is also generated by the digging activites of the various departments like the telephone, electricity, drainage, etc. Small-scale industries generate some wastes. For example, garment factory would dump textiles of various kinds. The sewer removed from the sewerage during cleaning is often left on the roadside. This poses several health hazards to the public. The biodegradable wastes are those that can be decomposed by the natural processes and converted into the elemental form. For example, kitchen garbage, animal dung, etc. The non-biodegradable wastes are those that cannot be decomposed and remain as such in the environment. They are persistent and can cause various problems. General classification of wastes is shown in Table 1.

3. Waste management

Waste management is one of the major environmental concerns in the world. Human activities and changes in lifestyles and consumption patterns have resulted in an increase in solid waste generation rates. Waste management can involve solid, liquid, gaseous or radioactive substances, with different methods and fields of expertise for each. A typical waste management system comprises collection, transportation, pre-treatment, processing, and final abatement of residues (Kan, 2009).

Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial, producers. When recycling began to be recognized as essential for both environmental and resource management reasons, recycling rates for household wastes in most developed countries in the 1980s were in the low single figures by percent. Modern western waste management systems have rebuilt recycling rates over the last 20 years (Wilson et al., 2009). Modern waste management systems, which many developing country cities aspire to, are all characterized by high recycling rates of clean, source separated materials.

A waste management concept including the following goals:

1. Reduction of total amount of waste by reduction and recycling of refuse.

2. Recycling and re-introduction of suitable groups of substances into production cycles as secondary raw material or energy carrier.

3. Re-introduction of biological waste into the natural cycle.

4. Best-possible reduction of residual waste quantities, which are to be disposed on “suitable” landfills.

5. Flexible concept concerning fluctuations in waste quantities and the composition of domestic waste. New developments in the field of waste management must be included into the system (AEVG, 2008).

Large quantities of this waste cannot be eliminated. However, the environmental impact can be reduced by making more sustainable use of this waste. This is known as the “Waste Hierarchy” (Batayneh et al., 2007). The waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify Table 1. General classification of wastes waste management strategies according to their desirability in terms of waste minimization. The hierarchy of disposal options, which categorizes environmental impacts into six levels, from low to high; namely, reduce, reuse, recycle, compost, incinerate and landfill (Siddique et al., 2008). The waste hierarchy remains the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

Nowadays not all the wastes are classified under the same classical category, requiring the same procedure of elimination. Especially in the industries in which the types of wastes are so varied it is very difficult and impractical to set up and operate a different management system for different types of wastes (Buyukbektas and Varinca, 2008). Thus has emerged the necessity of a, management system which would eliminate all types of wastes. Table 2 has presented a selection of promising waste treatment processes.

An integrated approach is required in an attempt to manage such large quantities of a diverse, contaminated mixture of wastes in an energy efficient and environmentally benign manner. This would require examining critically various steps in the life of the wastes such as the raw materials for their manufacture, the manufacturing processes, design and fabrication of the finished products, possible reuse of those items, and the proper disposal of the wastes, in totality. Such an integrated waste management concept comprises: (i) source reduction; (ii) reuse; (iii) recycling; (iv) landfill and gas-to energy (v) waste-to energy conversion.

Waste classification	Waste description
Type 1	A mixture of highly combustible waste, primarily paper, cardboard, wood, boxes and combustible floor sweepings; mixtures may contain up to 10% by volume of plastic bags, coated paper, laminated paper, treated corrugated cardboard, oily rags and plastic rubber scraps. Commercial and industrial sources.
Type 2	A mixture of combustible waste such as paper, cardboard, woodscrap, foliage, floor sweepings and up to 20% cafeteria waste. Commercial and industrial sources.
Type 3	Rubbish and garbage. Residential sources.
Type 4	Animal and vegetation waste from restaurants, cafeterias, hotels, etc. Institutional, club and commercial sources.
Type 5	Human and animal remains consisting of carcasses, organs and solid tissue wastes from farms, laboratories and animal pounds.
Type 6	Medical waste including sharps pathological, surgical and associated infectious waste materials.
Type 7	Department store waste.
Type 8	School waste with lunch programs.
Type 9	Supermarket waste.
Type 10	Other wastes (radiactive wastes, metallic wastes, gaseous wastes etc.).

Table 2. Selected waste treatment processes

Waste stream		Waste disposal methods
Combustible wastes		Roaster incineration
		Fluid bed incineration
		Pyrolysis-incineration
		Pyrolysis-gasification
		Separation-composting-incineration
		(Wet and dry) separation-digesting-incineration
		Separation-digesting-pyrolysis
		Separation-digesting-gasification
		Separation-digesting-incineration in a cement plant
		Selective separation-incineration
Non-combustible wastes		Landfill
Partially combustible waste streams	Wood	Pyrolysis and co-incineration in a coal power plant Pyrolysis and co-incineration in a powdered coal power plant Incineration in a fluid bed furnace Gasification
	Plastics	Gasification Feedstock Recycling
	Organic wastes	Composting Anaerobic Digestion

4. Energy from bio-wastes

Biomass energy is one of humanity's earliest sources of energy particularly in rural areas where it is often the only accessible and affordable source of energy. Biomass can be burnt directly or it can be converted into solid, gaseous and liquid fuels using conversion technologies such as fermentation to produce alcohols, bacterial digestion to produce biogas, and gasification to produce a natural gas substitute. Burning plant biomass as a fuel source does not result in net carbon emissions since the biofuels will only release the amount of carbon they have absorbed during growth (providing production and harvesting is sustainable). If these biofuels are used instead of fossil fuels, carbon emissions from the displaced fossil fuels are avoided as well as other associated pollutants such as sulfur.

Major byproducts of delignification processes of lignocellulosic biomass include lignin degradation products. Lignin and its degradation products have fuel values. However, pulp and paper mill waste is rich in cellulose and has a potential for ethanol production. Cellulose must be hydrolyzed to glucose before fermentation to ethanol. Conversion efficiencies of cellulose to glucose may be dependent on the extent of chemical and mechanical pretreatments to structurally and chemically alter the pulp and paper mill wastes. The method of pulping, the type of wood, and the use of recycled pulp and paper products also could influence the accessibility of cellulose to cellulase enzymes.

4.1. Biofuels from biomass

The term biofuel is referred to as solid, liquid or gaseous fuels that are predominantly produced from biorenewable or combustible renewable feedstocks. Liquid biofuels are important in the future because they replace petroleum fuels. The biggest difference between biofuels and petroleum feedstocks is oxygen content. Biofuels are non-polluting, locally available, accessible, sustainable and reliable fuel obtained from renewable sources. Electricity generation from biofuels has been found to be a promising method in the nearest future. The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers high-energy conversion efficiencies.

Biofuels can be classified based on their production technologies: First generation biofuels (FGBs); second generation biofuels (SGBs); third generation biofuels (TGBs); and fourth generation biofuels.

The FGBs refer to biofuels made from sugar, starch, vegetable oils, or animal fats using conventional technology. The basic feedstocks for the production of first generation biofuels are often seeds or grains such as wheat, which yields starch that is fermented into bioethanol, or sunflower seeds, which are pressed to yield vegetable oil that can be used in biodiesel. Table 3 shows the classification of renewable biofuels based on their production technologies.

Second and third generation biofuels are also called advanced biofuels. SGBs made from non food crops, wheat straw, corn, wood, energy crop using advanced technology. Algae fuel, also called oilgae or third generation biofuel, is a biofuel from algae. Algae are low-input/high-yield (30 times more energy per acre than land) feedstocks to produce biofuels using more advanced technology. On the other hand, an appearing fourth generation is based in the conversion of vegoil and biodiesel into biogasoline using most advanced technology.

There are two global liquid biofuels that might replace gasoline and diesel fuel. These are bioethanol and biodiesel. Bioethanol is good alternate fuel that is produced almost entirely from food crops. Biodiesel has become more attractive recently because of its environmental benefits.

Transport is one of the main energy consuming sectors. It is assumed that biodiesel is used as a fossil diesel replacement and that bioethanol is used as a gasoline replacement. Biomass-based energy sources for heat, electricity and transportation fuels are potentially carbon dioxide neutral and recycle the same carbon atoms. Due to widespread availability opportunities of biorenewable fuel technology potentially employ more people than fossil-fuel based technology.

Renewable liquid biofuels for transportation have recently attracted huge attention in different countries all over the world because of its renewability, sustainability, common availability, regional development, rural manufacturing jobs, reduction of greenhouse gas emissions, and its biodegradability.

Table 3. Classification of biofuels based on their production technologies.

4. 1. 1. Bioethanol

Bioethanol can be used directly in cars designed to run on pure ethanol or blended with gasoline to make "gasohol". Anhydrous ethanol is required for blending with gasoline. No engine modification is typically needed to use the blend. Ethanol can be used as an octane-boosting, pollution-reducing additive in unleaded gasoline.

Between 1991 and 2001, world ethanol production rose from around 16 billion liters a year to 18.5 billion liters. From 2001 to 2007, production is expected to have tripled, to almost 60 billion liters a year. Brazil was the world’s leading ethanol producer until 2005 when U.S. production roughly equalled

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2006. China holds a distant but important third place in world rankings, followed by India, France, Germany and Spain (Demirbas, 2008).

The continued increases in the price of crude oil in 2005 and 2006 resulted in a reversal of the traditional relationship between the price of biomass energy and that of crude oil, something not seen since the 1930s. As a consequence of the high prices of traded crude oil, many countries advanced their biofuel goals and, in the case of Brazil and the USA, large production gains occurred. Table 4 shows the world production of ethanol during 2004 and 2007.

Generation	Feedstock	Example
First generation biofuels	Sugar, Starch, Vegetable oils, or Animal fats	Bioalcohols, Vegetable oil, Biodiesel, Biosyngas, Biogas
Second generation biofuels	Non food crops, Wheat straw, Corn, Wood, Solid waste, Energy crop	Bioalcohols, Bio-oil, Bio-DMF, Biohydrogen, Bio-Fischer-Tropsch diesel, Wood diesel
Third generation biofuels	Algae	Vegetable oil, Biodiesel
Fourth generation biofuels	Vegetable oil, Biodiesel	Biogasoline

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Table 4. World production of ethanol during 2004 and 2007 (billion gallons)

Country	2004	2005	2006	2007	Growth rate 2006-2007	Share of total 2007
USA	3.40	3.90	4.86	6.49	33.5%	38.3%
Brazil	3.87	4.25	4.71	5.96	26.5%	35.2%
China	0.93	0.93	0.94	0.99	5.3%	5.9%
India	0.33	0.29	0.44	0.65	47.7%	3.8%
France	0.22	0.24	0.24	0.30	25.0%	1.8%
Others	2.00	2.10	2.40	2.55	6.3%	15.0%
Total	10.75	11.71	13.59	16.94	24.6%	100.0%

4. 1. 2. Biodiesel

The other significant biofuel is biodiesel, which is currently produced from vegetable oils, animal fats and grease by transesterification. The vegetable oils with carbon chain lengths of between 16 and 22 carbon atoms are generally in the form of triacyl glycerides (TAG) which on transesterification with methanol produce fatty acid methyl ester (FAME) as the precursor to biodiesel and glycerol as a by-product. Vegetable oil (m)ethyl esters, commonly referred to as "biodiesel," are prominent candidates as alternative diesel fuels. The name biodiesel has been given to transesterified vegetable oil to describe its use as a diesel fuel. After FAME purification and testing for compliance with either EN 14214 or ASTM D6751 standards the product can be sold as biodiesel and used as blends - typically B5 (5% biodiesel) to B20, depending on the engine warranties.

Biodiesel is technically competitive with or offer technical advantages compared to conventional petroleum diesel fuel. The vegetable oils can be converted to their (m)ethyl esters via transesterification process in the presence of catalyst.

Methyl, ethyl, 2-propyl and butyl esters were prepared from vegetable oils through transesterification using potassium and/or sodium alkoxides as catalysts. The purpose of the transesterification process is to lower the viscosity of the oil. Ideally, transesterification is potentially a less expensive way of transforming the large, branched molecular structure of the bio-oils into smaller, straight-chain molecules of the type required in regular diesel combustion engines.

The cost of biodiesels varies depending on the base stock, geographic area, variability in crop production from season to season, the price of the crude petroleum and other factors. Biodiesel has over double the price of petroleum diesel. The high price of biodiesel is in large part due to the high price of the feedstock. However, biodiesel can be made from other feedstocks, including beef tallow, pork lard, and yellow grease.

The commercial resource base for vegetable oils comprises about 20 different species with soybean oil, rapeseed (Colza), palm/palm kernel oil, sunflower, and coconut oils being the largest sources. Most of the biodiesel that is currently made uses soybean oil, methanol, and an alkaline catalyst. The high value of soybean oil as a food product makes production of a cost-effective fuel very challenging. However there are large amounts of low-cost oils and fats such as restaurant waste and animal fats that could be converted to biodiesel. The problem with processing these low cost oils and fats is that they often contain large amounts of free fatty acids (FFA) that cannot be converted to biodiesel using an alkaline catalyst.

Biodiesel is an environmentally friendly alternative liquid fuel that can be used in any diesel engine without modification. There has been renewed interest in the use of vegetable oils for making biodiesel due to its less polluting and renewable nature as against the conventional petroleum diesel fuel. If the biodiesel valorized efficiently at energy purpose, so would be benefit for the environment and the local population, job creation, provision of modern energy carriers to rural communities, avoid urban migration and reduction of CO_2 and sulfur levels in the atmosphere. Table 5 shows the biodiesel: production between 2004 and 2006.

Table 5. Biodiesel production (thousand tons)

	2004	2005	2006
Germany	1,035	1,669	2,681
France	348	492	775
Italy	320	396	857
Malaysia		260	600
USA	83	250	826
Czech Republic	60	133	203
Poland		100	150
Austria	57	85	134
Slovakia	15	78	89
Spain	13	73	224
Denmark	70	71	81
UK	9	51	445
Other EU	6	36	430
Total	2,016	3,694	7,495

The purpose of this analysis was to assess the economic feasibility of producing hydrogen from biomass via two thermochemical processes: 1) gasification followed by reforming of the syngas (H_2 + CO), and 2) fast pyrolysis followed by reforming of the carbohydrate fraction of the bio-oil. In each process, water-gas shift is used to convert the reformed gas into hydrogen, and pressure swing adsorption is used to purify the product.

Pyrolysis/cracking, defined as the cleavage to smaller molecules by thermal energy. Hydrogen can be produced economically from woody biomass. Biomass can be thermally processed through gasification or pyrolysis to produce hydrogen. The main gaseous products from biomass are the following:

Pyrolysis of biomass → H_2 + CO_2 + CO + Gaseous and liquid hydrocarbons (1)

Catalytic steam reforming of biomass → H_2 + CO_2 + CO (2)

Fisher-Tropsch synthesis of (H_2 + CO) → Gaseous and liquid hydrocarbons (3)

The conventional pyrolysis of biomass is associated with the product of interest that is the high charcoal continent, but the fast pyrolysis is associated with the products of interest are tar, at low temperature (675-775 K), and/or gas, at high temperature.

4. 2. Biogas production facilities from the organic fraction of MSW

In recent years the issue of ‘‘climate change” has dominated the field of decision-making for environmental policies. One of the numerous applications of renewable energy is represented by the use of upgraded biogas where needed by feeding into the gas grid (Pertl, 2010).

The first methane digester plant was built at a leper colony in Bombay, India, in 1859 (Meynell, 1976). Most of the biogas plants utilize animal dung or sewage. Anaerobic digestion is a commercially proven technology and is widely used for treating high moisture content organic wastes including +80%–90% moisture. Biogas can be used directly in spark ignition gas engines (SIGEs) and gas turbines. Used as a fuel in SIGE to produce electricity only, the overall conversion efficiency from biomass to electricity is about 10%–16% (Balat, 2009).

4. 3. Biohydrogen by anaerobic fermentation

Anaerobic hydrogen production proceeds photofermentative as well as without the presence of light. Anaerobic bacteria use organic substances as the sole source of electrons and energy, converting them into hydrogen.

$$\text{Glucose} + 2H_2O \rightarrow 2\text{Acetate} + 2CO_2 + 4H_2 \quad (10)$$

$$\text{Glucose} \rightarrow \text{Butyrate} + 2CO_2 + 2H_2 \quad (11)$$

The reactions involved in hydrogen production (Eqs. 6.3 and 6.4) are rapid and these processes do not require solar radiation, making them useful for treating large quantities of wastewater by using a large fermentor.

Since they cannot utilize light energy, the decomposition of organic substrates is incomplete. Further decomposition of the acetic acid is not possible under anaerobic conditions. Nevertheless, these reactions are still suitable for the initial steps of wastewater treatment and hydrogen production followed by further waste treatment stages.

A new fermentation process that converts valueless organic waste streams into hydrogen-rich gas has been developed by Van Ginkel et al. (2001). The process employs mixed microbial cultures readily available in the nature, such as compost, anaerobic digester sludge, soil etc. to convert organic wastes into hydrogen-rich gas. The biodegradation efficiencies of the pollutants were examined by changing hydraulic retention time (HRT) as a main operating variable. An enriched culture of hydrogen producing bacteria such as Clostridia was obtained by heat treatment, pH control and HRT control of the treatment system. The biohydrogen fermentation technology could enhance the economic viability of many processes utilizing hydrogen as a fuel source or as raw materials.

Anaerobic fermentative microorganism, cyanobacteria and algae are suitable in biological production of hydrogen via hydrogenase due to reversible hydrogenases (Balat, 2008). Cyanobacteria and algae can carry out photo-evolution of hydrogen catalyzed by hydrogenases. The reactions are similar to electrolysis involving splitting of water into oxygen and hydrogen (Gaffron, 1940).

Hydrogen producing bacteria (Clostridia) were found to have growth rates about 5 to 10 times higher than that of methane producing bacteria (Van Ginkel et al., 2001; Sung, 2004). In a continuous flow bioreactor system, hydrogen production showed declining trend at the later stage of reactor operation. Based on these findings, it is hypothesized that Clostridia may have gone through a phenomenon known as “degeneration” in which they lose their ability to produce hydrogen. Therefore inoculating fresh mixed cultures may be a feasible way to maintain a sustainable hydrogen production. Based on this hypothesis, two-stage anaerobic reactor has been proposed. The first-stage reactor is designed as hydrogen producing reactor whereas the second-stage reactor will be employed to cultivate fresh seed culture to perpetually supply to the first one. Fig. 7 shows the schematic diagram of the two-stage reactor system. The hydrogen producing reactor has a total volume of 5 liters with active volume of 3 liters. The second stage has a total volume of 22 liters, and the active volume is 18 liters (Sung, 2004).

6. Conclusion

All living organisms have to produce some kind of waste and it has to be collected to be taken elsewhere. Many cities and towns deals with solid waste by creating a landfill; some use incinerators to burn the trash. The best way to get rid of solid waste is use a method called composting. In the process of composting, solid waste collectors use natural biological progression to swiftly decompose garbage. Solid waste is a necessary in life. Hazardous waste is the most deadly because it can harm or kill animals, humans, plants, and environments. The wastes cover toxic chemicals, flammable substances, radioactive substances, industrial wastes from chemical plants and nuclear reactors, agricultural wastes, medical wastes, and residential wastes. One example of one of the worst disasters cause by hazardous wastes took place in 1986, when a nuclear reactor exploded near Chernobyl, Ukraine. Even though this calamity only killed 31 people and evacuated 200,000 people.

Waste to energy (WTE) technologies convert waste matter into various forms of fuel that can be used to supply energy**.** There are four major methods for conversion of organic wastes to synthetic fuels: (1) hydrogenation, (2) pyrolysis, (3) gasification, and (4) bioconversion.

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3/17/2013