International Journal of Scientific Research in Biological Sciences
Review Paper Volume-3, Issue-3 ISSN: 2347-7520

Food Waste to Energy Conversion Technologies

Venkatesh Mittal, Shivendra Vyas and Vaidehi Verma

Navsamvat College, Indore - India

Available online at www.isroset.org

Received: 16 Apr 2016 Revised: 17 May 2016 Accepted: 04 Jun 2016 Published: 30 Jun 2016

Abstract— Food waste mainly refers to the utilizing the food more than it is needed. Food waste represents a significant solid waste. Proper management and recycling of huge volumes of food waste are required to chop its environmental burdens and to lesser the risk to human health. Food waste is indeed untapped resource with great potential for energy production. Utilization of food waste for energy conversion currently represents the ultimate challenge due to multiple reasons. This includes high moisture contents and low calorific value which constitute for the development of healthy, large scale and productive industrial processes. Although many researchers have been carried out in this respect but there is lack of proper theoretical reviews. The present researches and knowledge available in this content involves biological, thermal and thermo chemical technologies. The advantages and challenges of these technologies are discussed in the research. In addition, the future direction for more effective utilization of food waste for energy generation are suggested from combining two or more technologies perspective

Keywords - Food waste, Energy conversion, biological, thermo, thermochemical

I. INTRODUCTION

Food waste mainly refers to the utilizing the food more than it is needed. Food waste represents a significant solid waste. Food waste or food loss is food that is discard or lost or uneaten. It occurs mainly at stage of production, processing, retailing and consumption.In India people waste as much food as the whole of United Kingdom consumes – a statistic that may not so much indicative of our love of surfeit, as it is of our population. Still, food wastage is an alarming issue in India. Our street and garbage bins, landfills have sufficient proof to prove it.
Weddings, canteens, hotels, social and family functions, households spew out so much food. According to the United Nations Development Programme, up to 40% of the food produced in India is wasted. About 21 million tons of wheat is wasted in India and 50% of all food across the world meets the same fate and never reaches the needy. In fact, according to the agriculture ministry, Rs. 50,000 crore worth of food produced is wasted every year in the country. The theme for this year's World Environment Day campaign is 'Think Eat Save'. It is an anti-food wastage and food loss campaign aimed at reducing the wastage footprint. India ranks 63 among 88 countries in Global Hunger Index. Wastage of food is not indicative of only hunger or pollution, but also many economic problems in the economy, such as inflation. Only government policies are not responsible for the problems we are facing today, but our culture and traditions are also playing a lead role in this drama.

Why is food wastage a problem?

- 25% of fresh water used to produce food is ultimately wasted, even as millions of people still don't have access to drinking water. When you calculate the figures in cubic kilometers, this is a bit more than an average river.

- Even though the world produces enough food to feed twice the world's present population, food wastage is ironically behind the billions of people who are malnourished. The number of hungry people in India has increased by 65 million more than the population of France. According to a survey by Bhook (an organization working towards reducing hunger) in 2013, 20 crore Indians sleep hungry on any given night. About 7 million children died in 2012 because of hunger/malnutrition.

Thus there is need to convert food waste into energy, so that on can actually get rid of the food waste and the pollution that it can cause. ThereforeProper management and recycling of huge volumes of food waste are required to chop its environmental burdens and to lesser the risk to human health. This realization has motivated fundamental research on technologies that help to recover some valuable fuels from food waste to reduce the environmental burden of its disposal, avoid depletion of natural resources, minimize risk to human health and maintain an overall balance in the ecosystem.

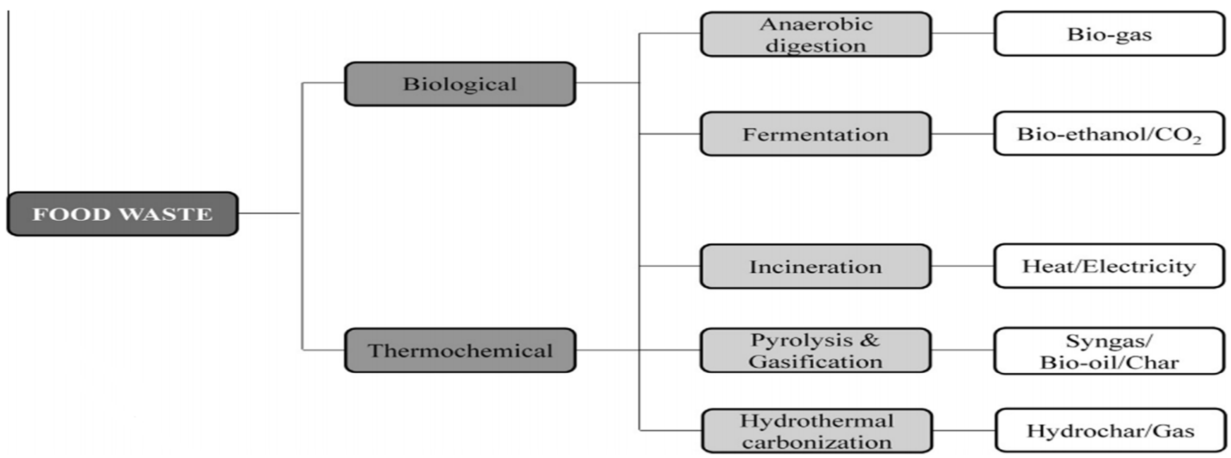
Energy conversion

Energy conversion, the transformation of energy from one form provided by nature to another form that can be used byhuman beings. Over the centuries a wide array of devices and systems has been developed for this purpose. Some of these energy converters are quite simple. The early windmills, for example, transformed the kinetic energy of wind into mechanical energy for pumping water and grinding grain.

In recent years, it has been recognized that food waste is an untapped resource with great potential for generating energy. Thus, energy recovery from food waste is an additional attractive option to pursue, particularly from the energy security viewpoint. This realization has motivated fundamental research on technologies that help to recover some valuable fuels from food waste to reduce the environmental burden of its disposal, avoid depletion of natural resources, minimize risk to human health and maintain an overall balance in the ecosystem. Although there has been a considerable amount of research focused on the conversion of food waste to renewable energy, there is a lack of comprehensive reviews of the published literature. McKendry (2002) reviewed various biomass-to-energy conversion technologies, but there was no specific emphasis on the use of food wastes as feedstock.

In the current research, we provide insights into various technologies that have been explored for food-waste-to-energy conversion including biological (e.g. anaerobic digestion and fermentation), thermal and thermochemical technologies (e.g. incineration, pyrolysis, gasification and hydrothermal oxidation). This research discusses the advantages as well as the major challenges associated with these technologies. In the light of recent technological advances and the drive towards using food waste as a raw material to both reduce the environmental burden of its disposal and address the concerns about future resources, this research identifies key knowledge in food-waste-to-energy conversion technologies. In addition, we suggest future directions for more effective ways of treating food waste for renewable energy generation from there source recovery viewpoint.

II. TECHNIQUES OF ENERGY CONVERSION FROM FOOD WASTE.



Summary of food-waste-to-energy technologies.

Food-waste-to-energy conversion processes.

Conversion process	Conversion process conditions	Main products	By-products
Incineration	400–540 °C	Heat, electricity	Ash
Pyrolysis	250–750 °C, absence of oxygen	Char, oil or tar, gas (CO, CH_4, hydrocarbons, H_2, CO_2 (content dependent on process conditions))	Char (use as oil amendment, activated coal or sorbent)
Gasification	350–1800 °C, air, oxygen or steam, 1–30 bar	Gas (CO, CH_4, N_2, H_2, CO_2 (content dependent on process conditions))	Ash
Anaerobic digestion	35–55 °C, anaerobic, reactor size 10–10,000 m^3	Gas (main components CH_4 and CO_2)	Sludge (use as fertilizer after proper treatment)
Ethanol fermentation	30–35 °C, pH 4.5–6.0 anaerobic	Ethanol, CO_2	Animal feed
Hydrothermal carbonization	180–350 °C, 4–45 bar, wet	Hydrochar and gas (main component CO_2)	Crude oil and process water (contains value-added chemicals)

Biological technologies

- Anaerobic digestion:-

Anaerobic digestion (AD) of organic wastes in landfills produces biogas comprising mainly CH4 and CO2, and traces amounts of other gases such as nitrogen (N2), oxygen (O2) and hydrogen sulfide (H2S) that escape into the atmosphere and pollute the environment. Under controlled conditions without oxygen, the same process has the potential to convert the organic wastes into useful products such as biofuels (e.g. biogas) and nutrient enriched dig estates which can be used as soil conditioners or fertilizers. With the introduction of both commercial and pilot AD plant designs during early 1950s, AD of organic wastes has received worldwide attention. AD has many environmental benefits including the production of a renewable energy platform, the possibility of nutrient recycling, and the reduction of waste volume.

- Ethanol fermentation:-

Compared to biogas, ethanol production from food waste involves a different approach for waste-to-energy conversion. Various food wastes have been utilized for the production of bio-ethanol, including banana peel, sugar beet pulp, pineapple waste, grape pumice, potato peel waste, citrus waste as well as cafeteria food waste and household food waste. Due to the complex nature of the lignocellulose component of food wastes, different pretreatment methods such as acid, alkali, thermal and enzymatic processes have been used in order to increase cellulose digestibility. Enzymatic hydrolysis is probably the most common pretreatment method in ethanol production from food waste. Achieved 29.1 g/L ethanol yield from food waste using both carbohydrates and amyloglucosidases. A similar yield (32.2 g/L) was obtained in the study of Uncu and Cekmeceliogluusing food waste treated with amylases. Although the pretreatment can facilitate ethanol production by increasing digestibility of cellulose, the soluble sugars can be degraded forming various inhibitors such as furfural, especially if the treatment is performed at harsh conditions and in the presence of alkali. In most cases, Saccharomyces Cerevisiae was utilized for fermentation, although Ban-Koffi and Han also used Zymomonas mobiles and Korkie et al.UtilizedPichia rhodanensis. S. Cerevisiae has the disadvantage in that it can only utilize hexose sugars, but other fermentative organisms can be used for utilization of pentose sugars for ethanol production. An ethanol yield of 0.43 g ethanol/g TS and 0.31 g ethanol TS was obtained for separated hydrolysis and fermentation and simultaneousscarificationand fermentation, respectively. Thus, an average energy content of 8.3–11.6 kJ/g TS could be estimated for ethanol produced from food waste based on 26.9 MJ/kg energy content of ethanol.

Thermal and thermochemical technologies

- Incineration:-

Incineration is a mature technology that involves the combustion and conversion of waste materials into heat and energy. The heat from the combustion process can be used to operate steam turbines for energy production, or for heat exchangers used to heat up process streams in industry. Incinerators are able to reduce the volume of solid wastes up to 80–85%, and thus, significantly reduce the necessary volume for disposal. While the combustion of solid wastes is an old technique, its use as a viable waste management strategy is still not fully accepted by some European Member states. The reluctance of some countries to rely on waste incineration is related to toxic air emissions containing dioxins and heavy metals generated from the earlier equipment and technologies. Thus, air pollution control measures have to be undertaken. Additionally, the incombustible ash usually constitutes a concentrated inorganic waste that has to be disposed of properly. As a result, waste combustion was viewed in a negative light and was even banned in some countries. With the improvement in air emission control systems, a new generation of facilities could be built, which conform to a stricter environmental regulatory regime, significantly decreasing potential human health effects. The improvements in combustion technology created favorable conditions for the construction of many new plants in different countries. These plants also gained importance with the addition of the energy recovery section. In recovering heat or producing electricity, solid waste combustion was viewed as a part of energy policies, seeking to reduce dependency on fossil fuels.

- Pyrolysis and gasification:-

Pyrolysis and gasification are both thermal processes. Pyrolysis converts food waste, in an oxygen-free environment, into bio-oil as the major product along with syngas (CO + H2) and solid bio-char. Gasification converts food waste into a combustible gas mixture by partially oxidizing food waste at high temperature, typically in the range, 800–900 C . The low calorific value gas produced can be burnt directly or used as a fuel for gas engines and gas turbines. The product gas can be used as a feedstock (syngas) in the production of chemicals (e.g. methanol). Considering the environmental concerns of incineration, pyrolysis, gasification, or both combined appear as alternatives to combustion in food T.P.T. Pham et al. Waste Management 38 (2015) 399–408 403 waste treatment. The solid waste gasification and pyrolysis are complex processes composed of a number of physical and chemical interactions that occur at temperatures generally higher than 600 C, and the exact temperature depends on the reactor type and the waste characteristics, in particular the ash softening and melting temperatures. The pyrolysis process degrades the waste to produce energy in the form of syngas, pyrolysis oil or tar and char (the remaining devolatilized solid waste residue). The gasification process has the merit of producing hydrogen-rich syngas, which can be used as a basic building block for producing valuableproducts as chemicals and fuel under a controlled amount of oxygen.

- Hydrothermal carbonization:-

Hydrothermal carbonization (HTC) is one of the thermal conversion technologies attracting increased attention from researchers, especially for waste streams with high moisture content (80– 90%). HTC was first experimentally introduced as a means to generate coal from cellulose in 1913. HTC is a wet process that converts food wastes to a valuable, energy-rich resource under autogenously pressures and relatively low temperature (180–350 C). A number of studies have recently focused on HTC covering a wide range of feedstock'sincluding lignocellulose biomass and MSW. Compared to other waste-to-energy conversion methods using biological processes, HTC has various advantages including smaller treatment footprints, greater waste volume reductions and no process-related odors. Additionally, HTC reaction takes only a few hours compared to days or months needed for biological processes. Furthermore, the high process temperature helps to eliminate pathogens and inactivates other potential organic contaminants. The process results in the production of a sterile, hygienic, easily stored and transported energy-rich resource. It is also likely that energy can also be recovered from the liquid increasing the energetics of HTC. There is a possibility to recover some of the chemicals from the HTC process water for use reuse.

Overall comparison of food-waste-to-enery conversion technologies in terms of environmental and energy-economic and health aspects.

Technologies		Anaerobic digestion	Ethanol fermentation	Incineration	Pyrolysis/ gasification	Hydrothermal carbonization
Environmental aspects	Greenhouse effect	++++	++++	+	+++	+++++
	Odor problem	+	++	+++++	+++++	+++++
	Air/water pollution	++++	+++++	+	+++	+++++
Energy-economic and health aspects	Human health	++	++++	+	+	+++++
	Process speed	+	+++	++++	++++	+++++
	Energy production yield	+	+++	+++	+++	+++++
	Relative cost	++	++	++	+++	+++

+ Very poor, ++ Poor, +++ Moderate, ++++ Good, +++++ Very good.

III. CONCLUSION AND FUTURE DIRECTION

In the light of rapidly rising costs associated with energy supply and waste disposal and increasing public concerns with environmental quality, the conversion of food wastes to energy is becoming an environmentally benign and economically attractive practice. Food waste compositions vary significantly based on their sources.

An overall summary of all energy conversion technologies in terms of environmental and energy-economic and health aspects is given. Although the HTC process for food waste has several advantages over other energy conversion technologies, there still remain some challenges and questions that should draw scientific attention for future directions in this research. The key research questions are (a) can we find a proper catalyst to lower the reaction temperature and pressure, especially for the high temperature HTC process?; (b) is it possible to digest food waste biomass by HTC to produce functional carbonaceous hydro charmaterials for their possible energy applications?; (c) what is the detailed chemical mechanism of low-temperature HTC &high temperature HTC as applicable to food wastes? and (d) how can we rationally design the HTC process to control the detailed components of the hydro charmaterials and liquid products? Since enzymatic pretreatment has recently been found to be beneficial to increase the yield of these products, it would be of scientific interest to further explore this enzymatic-assisted HTC process for production of fine chemicals from food waste. Solving these challenges and problems in the future will further facilitate and strengthen the capability for a rational design of a variety of hydro char materials and extended practical applications such as (1) CO2 sequestration, (2) energy generation (by co combusting with coal), (3) catalyst/adsorbent, (4) electric applications (Lithium ion batteries), and (5) soil amendments (soil nutrient cycles). Biological treatment methods possess advantages such as simplicity and low capital cost. However, it has the inherent disadvantages of a long treatment time and the possibility of inhibition of bacteria due to exposure to contaminants in food waste. Among thermal and thermochemical techniques, HTC is an attractive option for converting raw food waste into useful products such as hydro char, oil and other energy-rich compounds. However, a detailed techno-economic analysis has to be done to study the feasibility of using HTC for a large-scale operation. Finally, a systematic multi-disciplinary approach is needed with inputs from experts in the field to derive both short and long-term benefits in terms of energy and material recovery from the conversion of food wastes.

REFERENCE

[1] Arafat, H.A., Jijakli, K., Ahsan, A., 2013. Environmental performance and energy recovery potential of five processes for municipal solid waste treatment. J. Clean. Prod..http://dx.doi.org/10.1016/j.jclepro.2013.11.071.

[2] FAO-Food and Agriculture Organization, 2009. How to Feed the World in 2050. Food and Agriculture Organization.

[3] IPCC (Intergovernmental Panel on Climate Change), 2006. In: Eggleston, S., Buendia, L., Miwa, K., Nagara, T., Tanabe, K. (Eds.), Waste Generation, Composition and Management Data (Chapter 2).

[4] Kosseva, M.R., 2011. Management and processing of food wastes. In: Reference Module in Earth Systems and Environmental Sciences Comprehensive Biotechnology, second ed., pp. 557–593.

[5] Kosseva, M.R., 2009. Processing of food wastes. In: Taylor, S.L. (Ed.), Advances in Food and Nutrition Research, vol. 58, pp. 57–136.

[6] NEA Waste Statistics and Overall Recycling, 2012. <http://app2.nea.gov.sg/energywaste/waste-management/waste-statistics-and-overall-recycling>.

[7] Murphy, J.D., McKeogh, E., Kiely, G., 2004. Technical/economic/environmental analysis of biogas utilization. Appl. Energy 77 (4), 407–427.

