Food waste to energy conversion technologies

PROJECT REPORT

GROUP 18

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INTRODUCTION :

Food waste is a biodegradable waste discharged from various sources including food processing industries, hospitality sector and household. According to FAO, around 1.3 billion tonnes of food including fresh vegetables,meat, bakery, fruits and dairy products are lost along the food supply chain. The amount of Food Wastage is projected to increase in the next 25 years because of economic and population growth, mostly in the Asian countries. It has been reported that the annual amount of Food Wastage in Asian countries can rise from 279 to 417 million tonnes from 2005 to 2025.

Food wastage is becoming a critical problem around the globe because of the continuous increase of the world population. This large growth in food waste imposes serious threats to our society like environmental pollution, health risks, and scarcity of dumping land. There is an urgent need to take the required measures to reduce food waste burden by adopting standard management practices. Currently, various kinds of methods are investigated in waste food processing and management for environmental benefits and applications. Anaerobic digestion method appears as one of the most eco friendly solutions for food wastes management, energy, and nutrient production, which can directly contribute to world's ever-increasing energy requirements. Here, we have described and explored the various aspects of anaerobic bio degrading approaches for food waste, effects of co substrates, effects of environmental factors, contribution of microbial population, and the available computational resources for food waste management researches. Apart from the environmental challenges posed, the inherent complexity of food waste composition makes it a very attractive source of value-added products. Most of the materials generated as wastes by the food-processing industries contain components that can be utilized as substrates and nutrients in a variety of microbial or enzymatic processes. It has been recognized in recent years,that food waste is an untapped resource with great potential for generating energy. Thus, energy recovery from food waste is an attractive option to pursue.

OBJECTIVE :

In this report, we provide insights into the various technologies that have been explored for conversion of food waste to energy including biological, thermal and thermochemical technologies. This report discusses the advantages as well as the major challenges posed with these technologies. In the light of recent technological advances and the drive towards using food waste as a raw material to reduce the environmental burden of its disposal and also address the concerns about future resources, this report identifies key knowledge in food-waste-to-energy conversion technologies. Also, future directions for more effective ways of treating food waste for renewable energy generation from the resource recovery viewpoint are suggested.

CURRENT TECHNOLOGIES FOR ENERGY GENERATION FROM FOOD WASTE :

1. THERMAL AND THERMOCHEMICAL TECHNOLOGIES :

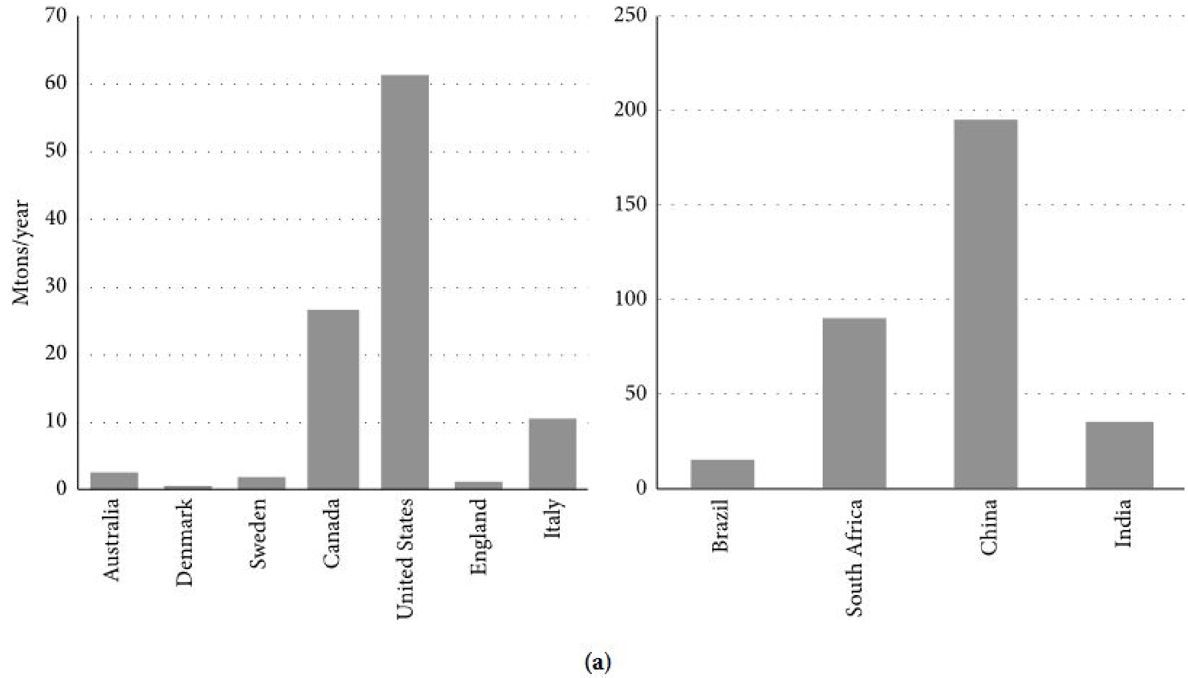
- ***Incineration*** : Combustion(or incineration) is the oldest, most common and well-proven thermal process using a wide variety of waste fuels. Municipal and household waste is directly combusted in large waste to energy incinerators as a fuel with minimal processing known as mass burning. Incineration 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 80–84%, and therefore, significantly reduce the necessary volume for disposal. Heat recovery systems and air-pollution control systems are now incorporated into most of the modern waste incinerators.The mass burning process burns the waste as it is received thereby eliminating the need to process the material prior to burning except for the removal of oversized items and obvious non-combustible metallic materials.The problem with this mass burning approach is that after combustion, the incinerators ash and other pollutants removal system must be capable of disposing off of every bit of the size and capacity of the combusted material coming out of the incinerator as it is going in.

- ***Pyrolysis and Gasification*** : These both are thermal processes. Food waste is converted, in an oxygen-free environment, into bio-oil as the major product along with syngas and solid bio-char by pyrolysis. Gasification converts the food waste into a combustible gas mixture by partially oxidizing food waste at a high temperature, typically in the range, 850–900°C. The gas produced which has a low calorific value can be burnt directly or used as a fuel for gas engines and gas turbines. The gas product can be used as a feedstock in the production of chemicals. While the combustion of waste to energy converts the fuel waste into energy directly on-site, thermal gasification of the waste materials allow the production of a gaseous fuel that can be easily collected and transported.
- ***Hydrothermal Carbonization*** : Hydrothermal Carbonization is a process that converts food wastes to a valuable, energy-rich resource under autogenous pressures and relatively low temperature (190–350°C). Compared with other waste-to-energy conversion methods using biological processes, Hydrothermal carbonization gives various advantages including smaller treatment footprints, greater waste volume reductions and no process-related odors. Additionally, Hydrothermal carbonization reaction takes only a few hours compared to days or months needed for biological processes.

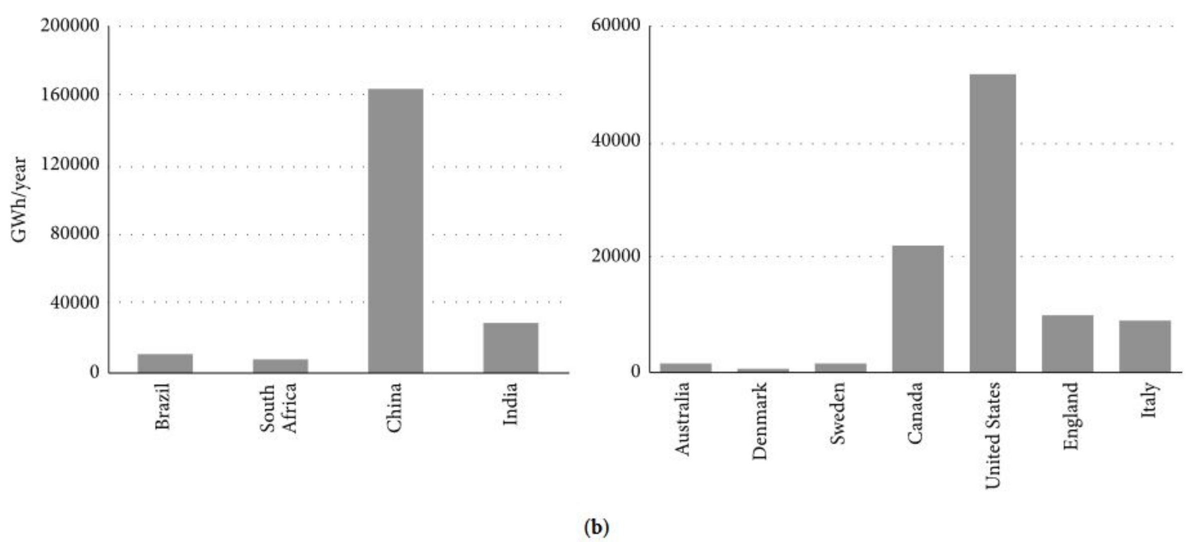
2. BIOLOGICAL TECHNOLOGIES :

- *Anaerobic Digestion* : An appropriate solution for food waste management is generation of methane through an anaerobic process. Anaerobic digestion of organic wastes in landfills produces biogas comprising mainly CH_4(methane) and CO_2(carbon dioxide), and trace amounts of other gases such as N_2(nitrogen), O_2(oxygen) and H_2S(hydrogen sulfide) that escapes into the atmosphere and pollutes the environment. Under controlled conditions without the oxygen, the same process possesses the potential to convert organic wastes into useful products such as biofuels (e.g. biogas) and nutrient enriched digestates which can be used as soil conditioners or fertilizers. It was reported that 1 m^3(1000L) of biogas from Anaerobic Digestion is equivalent to 21 MJ of energy, and it could generate 2.05kW h of electricity considering the 36% of generation efficiency.
- ***Ethanol Fermentation*** :Compared to biogas, in Ethanol fermentation, ethanol production from food waste involves a different approach for waste-to-energy conversion. Enzymatic hydrolysis is probably the most common pretreatment method in ethanol production from food waste. Although ethanol production can be facilitated by the pretreatment by increasing digestibility of cellulose, the soluble sugars can be

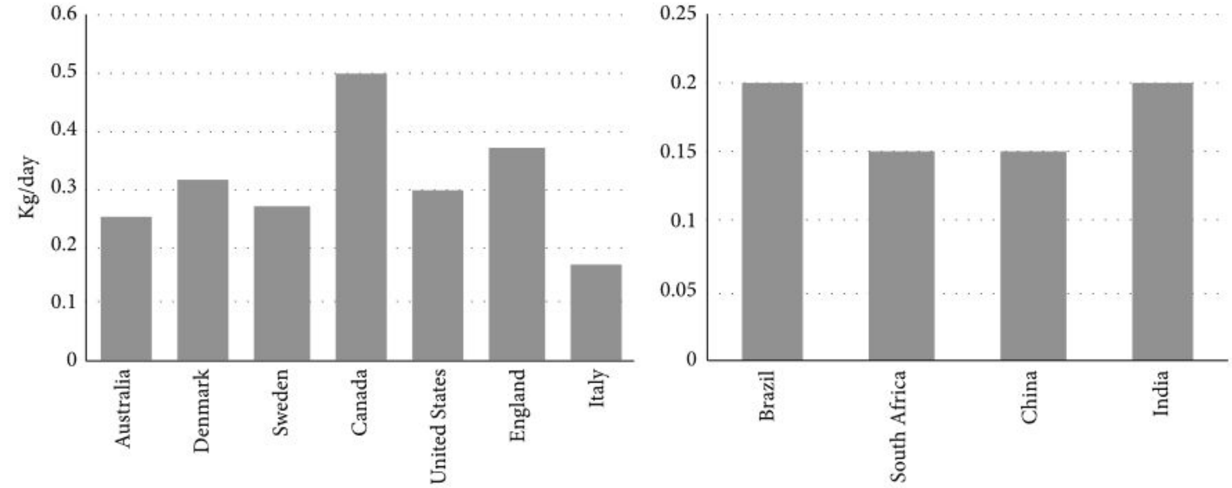
degraded which form various inhibitors such as furfural, especially if the treatment is performed in harsh conditions and in the presence of an alkali.



(a) Worldwide generation of food waste in developed and developing countries.



(b) **Worldwide bioenergy potential from Food Wastage in developed and developing countries.**



(c)

(c) **Per capita food waste generation in developed and developing countries.**

SUMMARY AND CONCLUSION :

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.

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. Some important characteristics of food wastes that have been reported include a moisture content of 74–90%, volatile solids to total

solids ratio of 0.8–0.97, and carbon to nitrogen ratio of 14.7–36.4. Because of relatively high moisture contents of food waste, common thermal treatments such as incineration, pyrolysis and gasification are considered energetically unfavorable. Besides the loss of organic matter and nitrogen, various environmental pollution problems which may arise as a result of the absence of proper air pollution control measures associated with incineration provided a strong impetus for the search for alternative, environment friendly methods of handling food wastes. Pyrolysis and gasification processes are favorable in terms of reducing CO2 emissions and operation costs compared to incineration. However, the utilization of food waste in this area is not devoid of challenges, due to variability of waste compositions which significantly influence the processes. The key issues are the high moisture contents, lower heating values and highly heterogeneous nature of food wastes, which result in technical and economic problems while using pyrolysis and gasification.
The conversion of food waste into energy via anaerobic processes in terms of methane appears to be economically viable. However, difficulties pose due to the collection as well as transportation of food waste should also be considered.
Recently , enzymatic pretreatment has been found to be beneficial to increase the yield of these products, therefore it will be of scientific interest to explore further, the enzymatic-assisted HTC process for production of fine chemicals from food waste. Biological treatment methods have the 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.

CASE STUDY : **https://www.sciencedirect.com/science/article/pii/S1877705816308529**
Biogas from Organic Food Waste by Mohamad Y. Mustafaa ,* , Rajnish K. Calayb, E. Románc, 8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

This paper presents a case study to investigate the potential for upgrade of a bio-waste treatment plant. The plant considered in this study is located in Nord Trøndelag County in central Norway. It's actual "waste-zone" covers an area of 98200 km2, with a population of 230000 inhabitants.

The performance of an anaerobic digester receiving domestic food waste over a period of 426 days was monitored and showed that for each tonne of input material the potential recoverable energy was 405 kWh. Volatile substance added with a methane content of around 62%. They observed high ammonia concentration in the digester, which could have been due to high nitrogen from the volatile fatty acids in the food waste. In another study, the bio-cycle anaerobic digester in South Shropshire, UK was monitored over a period of 14 months and again found that the source-segregated waste was readily biodegradable and produced a biogas with 60% methane. The process had a very favourable energy balance with around 400 kWh of energy recoverable from each tonne of waste processed. Those studies offer guidelines for the expected yield of biogas from the treatment of municipal solid waste.

By using the atomic analysis of various types of wastes, and the atomic weights of the respective elements, the average molecular structure of organic compounds in food waste can be approximated by the molecular composition $C6H10O4$.

The maximum amount of natural gas that may be generated during anaerobic decomposition can be determined from the approximate, simplified molecular formula
$C6H10O4 + 1.5H20 \rightarrow 3.25CH4+2.75CO2$
Modestly assuming that the thermal efficiency of electricity generation at the plant is 25%, and considering the Lower Heating Value (LHV) of methane (which is 50,000 kJ/kg), the total electricity produced per tonne of waste material will be according to equation:
133.5[kg/tonne]*5000[KJ/kg]*0.25=1668750 KJ/tonne
Hence, the expected theoretical output electricity from the solid waste = 463.5 kWh/tonne This analysis is used in this work to evaluate the actual output of the plant against the theoretical expected output to investigate causes of lower productivity and potential for upgrade of outputs. (ABP=Animal by product waste)

The addition of ABP waste to food waste has a positive effect on the produced biogas and digestate quality. An increase of 14%, in the amount of digestate in year 2 as compared to year 1 is observed. When this value is related to the increase in inputs to the plant, which is 17%, it can be concluded that a greater amount of waste has been converted to useful biogases, but this cannot be absolutely confirmed as this percentage lies within the error limits of the measurements.

Conclusions :

The types of inputs to a waste treatment plant were monitored over the period of two years to study the effects of various types of waste on the product of biogas and bio-rest. (ABP=Animal by product waste)
The following observations were concluded:

- An increased percentage of ABP reflects positively on the quality and amount of biogas produced, but of course, to the extent that does not inhibit the digestion process or lead to operational problems in the plant due to the accumulation of fatty acids and lipids.
- The addition of controlled amounts of ABP will increase the methane yield and improve the quality of the produced biogas.

- The amount of methane produced by the plant could be increased significantly when comparing actual yield to the theoretical expected yield from the plant. The reduced production could be the result of inhibited anaerobic process or due to functional problems in the plant, which need to be further investigated and considered.
- Actually produced electricity was around 35% of the theoretical potential, which can be improved by optimising the process.

REFERENCES :

https://www.sciencedirect.com/science/article/pii/S0956053X14005819?via%3Dihub
https://www.hindawi.com/journals/bmri/2017/2370927/
http://www.alternative-energy-tutorials.com/energy-articles/waste-to-energy-conversion.html