

Chapter 1

Introduction

1.0 Introduction

The amount of waste generation is rising day by day with growing population. This has a direct impact on the environment and the economy. According to the World Bank, global waste generation is anticipated to grow 70% by 2050 [1]. At present, organic waste accounts for approximately 46% of the global solid waste [2]. In 2016, the amount of organic waste generated around the world was up to 2.01 billion tonnes [3]. Up to 43% of the global waste originates from Europe along with East and Middle Asia. On the other hand, the Central East and North African regions make the least amount of waste and accounts only 15% of the global organic waste [4]. The waste disposal management are hugely reliant on the industry and waste type. The first category of waste generated is non-biodegradable waste such as glass, home stuffs, metals and plastics. On the other hand, organic waste is biodegradable. It comprises of garden waste, leftover food, rotten fruits, animal waste, vegetables and fruit peels, etc [2]. Figure 1. 1 represents the fractions of the organic waste present in the total volume of waste on a global scale [2].

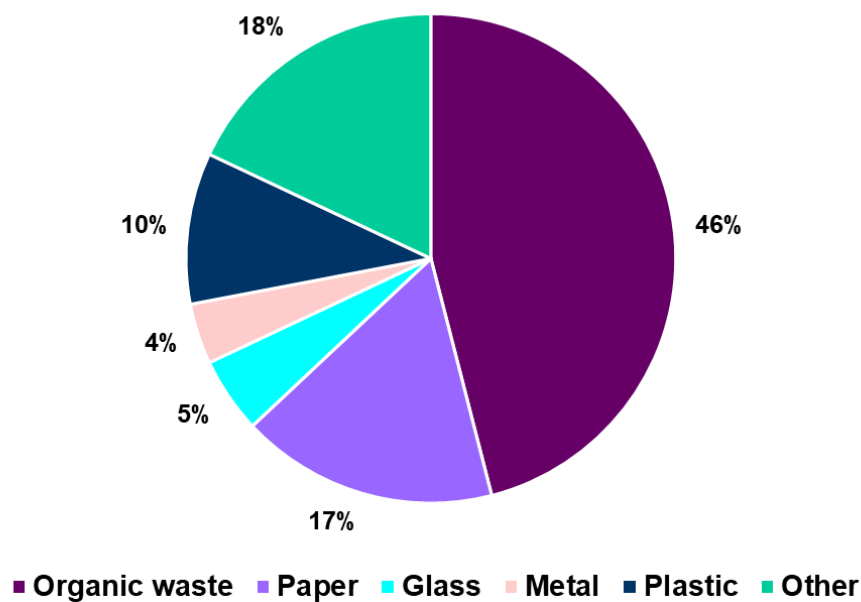


Figure 1. 1. Outline of global organic waste generation

Inappropriate disposal of organic waste generates pollution that is hazardous for the environment and human health. In anaerobic conditions, organic waste decomposition generates harmful greenhouse gases (GHG) such as methane. GHG emission is a key contributor in global warming [5]. Landfilling, open dumps, sanitary landfilling, composting and incineration are mainstream methods for waste disposal. Open dumps and land filling are two widely applicable waste disposal method worldwide [5], [6]. Globally, around 85% of the collected waste is dispensed into landfills and open dumps. Just 15% of the total collected waste undergoes recycling [7]. Both landfills and open dumps do not use waste as a resource, which is highly required strategy in the waste management policies. Both are the poor alternatives as they take up a lot of area, involve leakage, deplete landfill area, pollute air, water and soil. In addition, landfills have a limited lifetime and it is just not feasible for us to continue ruining precious land by constructing new landfills [8]. Incineration is another method of waste disposal. However, the installation of incineration plant is quite expensive, due to its costly equipment, infrastructure and regular maintenance. The smoke generated from the incineration include particulates, acid gases, carcinogen dioxin, and nitrogen oxide. These gases are toxic for the living beings and environment [8]. Prior to direct disposal of waste, reuse and recycling of waste materials are highly recommended for waste management policies.

Fruit waste refers to non-edible/rotten or indigestible parts that are generated during harvesting, handling, transport and food supply chain [9]. Fruit waste has high content of lignocellulose which can be easily used in the generation of renewable energy [10]. Therefore, there is an immediate need to implement technologies which can degrade fruit waste with simultaneous generation of renewable energy [11]. Such technologies are also expected to halt environmental issues like greenhouse gas emissions (methane, carbon dioxide) and soil leaching [12]. Various efforts have been made in past to obtain an efficient renewable energy from the fruit waste.

Treating fruit waste is a challenging task because it has a complex composition, high moisture and organic content [11], [13]. Disposing, burning and composting of fruit waste impact environment negatively [14]. Due to environmental contamination and insufficient resource recovery, the afore mentioned disposal methods are not appropriate for managing fruit waste [11]. The microbial fuel cell (MFC) system is known for its optimistic potentials such as the compatibleness, compactness and cleanliness [15]. MFC is also a convenient technology for waste resource recovery, wastewater remediation along with power generation.

MFC is a bio electrochemical device that uses electrons originating from the anaerobic oxidation of organic compounds to generate electricity [16]–[18]. MFC operates on following mechanisms for the elimination of pollutant: (i) oxidation of pollutants (agricultural waste, food waste) at anode chamber, (ii) reduction of pollutants, (iii) adsorption of pollutants on biofilms, (iv) effect of electrical field on chemical formulation of pollutant, (v) transfer of proton towards cathode which changes the pH of catholyte, (vi) reduction at cathode [19]. Many studies have shown the use of convenient organic/inorganic materials found in wastewater as a substrate for power generation [20]. The use of waste as a source of energy offers two benefits: firstly, it helps to manage waste and secondly, the power generated is highly cost effective. Many studies have shown that agricultural wastes are oxidised by various microorganisms, which lead to production of energy [21]. MFC is an innovative way for the valorisation of fruit waste biomass. Moreover, waste management strategies promote the recovery of valuable by-products and energy from waste biomass prior to its disposal. Various studies have explored the potential of fruit waste such as lemon [22], lime [22], orange [22], [23], tangerine [22] and blueberry waste [24] as substrate in MFC. Power generation in MFC is basically linked to the growth of electrogenic microorganisms and extracellular electron transfer rate [16]. Growth of anodic microbial community is affected by various parameters such as temperature, pH and availability of nutrients [25]. It is necessary to be aware of the

physiological response of microorganism towards the operating conditions. By providing the correct combinations of culture conditions, the power generation efficiency can be improved. Temperature is a vital aspect for microbial growth as it influences metabolic actions like enzyme activity, respiration and biomass productivity [26]. pH of the anolyte drastically influences the microbial physiology. It plays a significant role in the bioelectricity generation from MFC [27]. Additionally, temperature, pH and substrate concentration also impact the growth of microbial population and influences MFC performance [28]. Optimum concentration of substrate varies with the microbial diversity. Hence, it is difficult to determine optimal concentration range of substrate. The optimization becomes vital to reduce operational cost. The traditional response surface methodology (RSM) technique to optimize input variable of MFC has been widely used [29]–[34]. RSM analysis fits data to a second-order polynomial. RSM optimization works well only if curvature can be fitted to second-order polynomial. Besides this, RSM estimates error using least squares [35]. RSM requires selecting acceptable operational parameter ranges and restricts optimisation to specified scales [36], [37]. RSM cannot work with larger models and predict future outcomes for a system operated outside the range [36], [37]. It receives poor optimization results when operated with large range of responses [36], [37]. Machine learning (ML) can be endorsed to replace the conventional RSM technique. ML models deliver a new way to evaluate the response surface function which is problematic in the conventional RSM method [35]. A number of optimization methods have been also developed by ML. ML needs the pre-acquisition of a massive volume of experimental data (size of samples should be greater than the extent of coefficients to be evaluated) [35]. ML algorithms promptly evaluate a wide-range of dataset and reveal the most reasonable combinations of predictor variables for increasing current and power density. Patterns spotted using ML algorithms can contribute in building highly productive experimental designs [35].

The present work aimed at the valorisation of organic waste like banana peel, sweet lemon peel, mixed fruit peels, newspaper, dried algae biomass, cow urine, and spent engine oil as substrate for MFC. *Saccharomyces cerevisiae* has been used as anode biocatalyst. In the first objective, a newly isolated strain *Enterobacter cloacae strain IIT BHU M2V2* (cellulolytic bacteria) and *Saccharomyces cerevisiae* was co-cultivated for degradation of sweet lime peels at anode chamber of microbial fuel cell. In the second objective, newspaper powder, dried dead microalgae biomass and mixed fruit peel powder were separately targeted as substrate for the growth of *Enterobacter cloacae strain IIT BHU M2V2* inside the anode chamber of three different MFCs. Thereafter, in the third objective, comparative analysis of the banana peel waste and its potential to generate electrical energy in dried powdered and slurry formed under the influence of *S. cerevisiae* and indigenous microbial consortia has been investigated. At last, fourth objective aims at the application of a decision tree regression algorithm to optimise the operational parameters of an MFC utilising *S. cerevisiae* as anode biocatalyst and banana peel slurry as substrate.

