

Generation of Electricity from Agricultural Waste

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Abstract

The great contamination caused by organic waste in the process of sale and production has generated great governmental problems; mainly due to the lack of an adequate system for collecting waste. This research reveals the great potential of organic waste, mainly fruit waste, as fuel for the generation of electrical energy through the use of microbial fuel cell technology, due to the high content of chemical substances for chemical oxidation-reduction reactions. This research reveals the reason and the fundamental role for microorganisms in the process of generating electricity; as well as the advances revealed by researchers on the use of certain waste as fuel.

Keywords: organic waste, bioelectricity, bioreactor, waste fruit

1. Introduction

Due to a great increase in the economy and population worldwide, a series of problems have arisen, the main ones being scarcity of fossil fuels (gasoline, kerosene, etc.) for the generation of electricity and the increase in organic waste (waste of agriculture, municipal waste, industrial waste, chicken waste, plastic waste, etc.), which have significant environmental hazards due to the excessive release into the environment of approximately 16% of greenhouse gases (CO₂, CH₄, N₂O, etc) worldwide [1]. As a result, the European Environment Agency in 2020 has pronounced and adopted measures to promote sustainable management of biowaste as well as its reduction, because this component is almost 34% of municipal waste in the European Union (EU), with the goal of recycling 65% of municipal waste by 2035 [2, 3]. In addition, it is known that approximately 60% of municipal waste corresponds to food waste (fruits, vegetables, packaged products, etc.), and that each year approximately 88 million tons of food waste are produced, 173 Kg per person. Of note, food in the EU and UK corresponds to 20% of all food produced for human consumption [4]. Due to the large amount of waste available, new techniques and methods have emerged for the reuse of these types of waste, for example, as fertilizers, soil quality improvers, filters for water purification, biogas

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generation, bioelectricity, etc. [5]. Until a competent organization comes into force for the collection of organic waste or the provision of possible beneficial alternatives to the society, this will continue to be a problem for the governments of the day, the alternative is a strategy to insert these types of products in a circular economy, turning this solution into a challenge for the political agenda for the coming years. The example of Italy can be used, which has a strong policy on waste separation at the municipal level, generating a good fragmentation of the waste management system, optimizing the chain of reuse of the different types of waste in different fields [1, 6, 7].

2. Importance of fruit waste

At present, the use of fruit waste is very advantageous because it can be used as a substitute for some dangerous chemicals, but due to the economic aspect it is disadvantageous since it demands higher costs for its operation. This type of waste being a rich source of proteins, minerals, carbohydrates and several bioactive compounds becomes a benign environmental source that is readily available, inexhaustible, and abundant [8]. For the year 2050, it is estimated that the horticultural sector will increase its production to 10 billion tons due to the increase in population, which would increase the production of waste in this area, but modern horticulture needs to modernize, integrating proposals for technological innovation obtained from derived sectors or adjacent values, in such a way as to involve the bioindustry through a circular economy strategy [9]. In this sense, great progress has been made in the use of fruit waste as fuel for the generation of electricity, using the technology of microbial fuel cells (MFCs). This technology is relatively new, it consists of two chambers (anodic and cathodic) which are almost always joined by a proton exchange membrane inside the cells and an external circuit on the outside through which the electrons that generate the electric current circulate. [10, 11]. These MFCs use the chemical energy of the substrates (fuel or organic waste) and convert them into electrical energy through the process of oxidation (anode chamber) and reduction (cathode chamber). It has been observed that higher values of voltage and electrical current are obtained in single-chamber MFCs with cathode electrode exposed to the environment [12]. In particular, these types of initiatives will lead the future of the circular economy of horticulture, due to the excellent economic benefits that they will bring.

3. Role of microorganisms in electricity generation

Microorganisms are ubiquitous in nature and play an important role in the recycling of organic compounds. Their ability to exchange electrons significantly affects the bio-economy and is a property used by MFCs [13]. Their presence in MFC substrates is an important factor in generating electrical energy, since they are the main cause

of the transformation of the chemical energy contained in organic matter into electrical energy [14]. In recent years, new species that can generate electrical current in MFCs have been reported; however, there are few strains that can generate large voltage potentials such as those generated by mixed communities [15]. Typically, in MFCs the electrons travel from anode to cathode through a closed circuit, combining with protons to finally be captured by an electron acceptor (usually oxygen) and produce reduced compounds. These electrons are obtained when electrically active microorganisms carry out processes of oxidation of organic matter [16]. These microorganisms that transfer electrons to a solid anode are also called exoelectrogens, and the microorganisms that accept electrons are called electrophytes [17].

There are several mechanisms that drive the generation of electricity by microorganisms in an MFC, of which, the transfer of extracellular electrons to the anode is one of the most important, where exoelectrogenic bacteria can transfer electrons through three mechanisms. The first is the direct transfer of electrons in which biofilms are formed on the electrode, upon contact with cytochrome - a protein that transfers electrons from the cytoplasm to the outer membrane of the cell [18]. The second is electron transfer via redox mediators or naturally secreted soluble electron carriers such as flavins and pyocyanins. Finally, long-range electron transfer through conductive pili or nanowires [19]. In the case of fruits, they contain a series of sugars, minerals, vitamins, amino acids, polyphenols, aromatic compounds, carotenoids, fibers and phytosterols. Glucose is an important fuel in most organisms that, during glycolysis, is phosphorylated and split to form two molecules of glyceraldehyde-3-phosphate, each of which are later converted into a pyruvate molecule [20]. A small amount of energy is captured in two molecules of adenosine triphosphate and one of nicotinamide dinucleotide and reduced adenine, the latter being a molecule located in the cytosol as a product of glycolysis that serves as a mediator in the electron transport system to the electrical circuit in an MFC. [15]. Microorganisms can be aerobic and anaerobic. In anaerobes, pyruvate is converted into waste products in which NAD^+ is regenerated, continuing with glycolysis; while in aerobes, pyruvate is converted into acetyl-CoA and then into CO_2 and H_2O , with the release of electrons and protons [21, 22].

4. Case studies: fruit waste as generators of bioelectricity

In the search for possible solutions for the use of fruit waste, research groups have reported promising results for the generation of bioelectricity from these types of waste. The wastes of *R. ulmifolius* (blackberry), *H. undatus* (dragon fruit), and *M. citrifolia* (noni) were used as fuel in single-chamber MFCs, generating peak voltage values of 1.17 ± 0.12 V, which were configured in series, managing to turn on a red LED spotlight for 21 days [23]. In the same way, the use of waste from lime

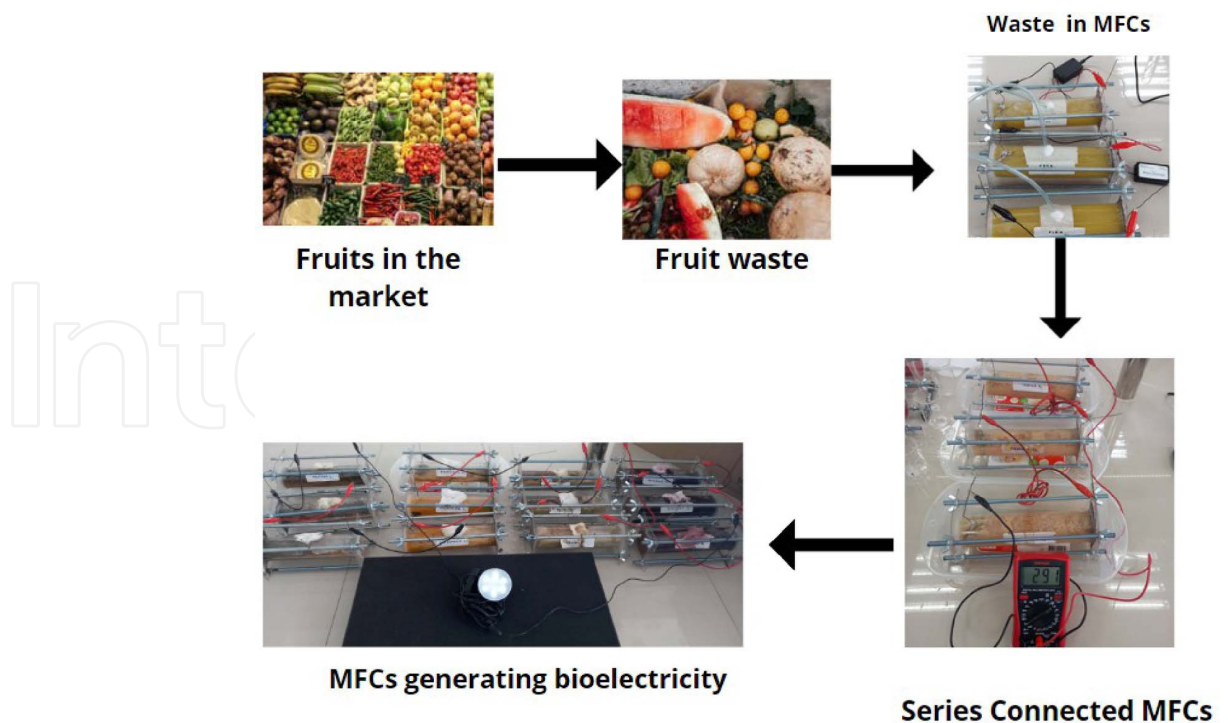


Figure 1. Schematization of the electricity generation process through fruit waste.

(*Citrus × aurantiifolia*), orange (*Citrus × sinensis*), and tangerine (*Citrus reticulata*) as fuel in single-chamber MFCs has been reported, managing to generate peak voltages greater than 1 V in all the cells with the different substrates. These excellent results are possibly due to the electrodes used in the cells that, being metallic (copper and zinc), allowed a lower resistance to the passage of the electrons generated in the anode chamber [24]. One of the most interesting cases reported is where blackberry waste is used as fuel, which was donated by the agricultural company Hortifrut S.A. (Trujillo, La Libertad, Peru), whose research managed to generate peak values of 1.127 ± 0.096 V and 1.130 ± 0.018 mA of voltage and current, respectively; becoming the investigation with the highest electrical parameters reported with no extra chemical component added to its waste during its monitoring, that is, it operated at normal environmental conditions [25]. In the same way, papaya waste has been used as fuel in MFCs, managing to report voltages close to 1.029 ± 0.131 V and 5.57 ± 0.45 mA. Likewise, they managed to molecularly identify the bacteria *Achromobacter berrezinae* and *Stenotrophomonas maltophilia* with a percentage of 99.32% and 100.00%, respectively, as the main bioelectricity-generating microorganisms [26]. Figure 1 shows the schematization of the bioelectricity generation process through organic waste, where MFCs connected in series using fruit waste were able to turn on a 6-watt bulb connecting 12 cells in series.

5. The future of using waste as fuel is a reality

In general, the excellent qualities of fruit waste for the generation of bioelectricity are being verified, based on the promising results that have begun to be obtained from its use as fuel. In the future, industrial companies (exporters and importers) of different types of fruits, as well as society and farmers as a whole, will be close. They will be able to use their own waste as a source of energy to produce electricity for their homes or businesses, which will reduce the costs generated in their daily activities. Many collection centers for these wastes will be tempted to separate their own waste because they will obtain an economic benefit from the reuse of their own waste. Although at present there are still barriers to bring this technology to a large scale, mainly as a consequence of the expenses in maintaining these types of devices, the metallic materials combined with the oxide compounds give a ray of hope for the emergence of this technology on a large scale. This technology would then provide renewable energy using low-cost raw material (organic waste), giving the opportunity to communities far from the main cities to access electricity and provide the necessary electrification to sustain the basic activities of mankind.

Conflict of interest

The authors declare no conflict of interest.

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