Hydrogen energy storage cuba

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Many emerging alternative technologies are geared towards providing cleaner energy, and are being implemented in many places around the world. However, their costs are generally high, and most developing countries are not able to invest in the infrastructure needed to harness them. Another drawback of some forms of alternative energy is the fluctuating production. Therefore, the conversion to a form of storable fuel in order to meet energy demands is required, increasing the cost of their use even more (Kalia and Purohit, 2008).

Some of these alternative energies include: thermonuclear energy, solar energy, wind energy, hydroelectric energy, radiant energy, tidal energy, and bio-fuels. Unlike most alternative energies, biofuels can be stored and later transported for use. Biofuels are fuels produced by living organisms that tend to be cheaper than other renewable alternative energies as they can be generated from biological wastes and water (Kalia and Purohit, 2008).

There are multiple methods to biologically produce hydrogen, which include the use of fermentative hydrogen-producing bacteria, microbial electrolysis cells, biophotolysis, among others. These methods, aside from being more affordable than other energy producing techniques, are non-polluting and can be used in developing nations by utilizing already existing bio-wastes.

The Republic of Cuba encompasses over one hundred thousand square miles of land of which over 50% is arable. It is located approximately 90 miles away from the United States and lies at the entrance of the Yucatan Peninsula, making this country of great geographical importance from a trade perspective.

These changes further deteriorated the Cuban economy, and have negatively impacted sugarcane production (Peters, 2003). Figure 1 illustrates the locations of Cuba"s sugar mills. Considering that the sugarcane mills in Cuba are well distributed across the island, transportation costs are minimal and appealing if sugarcane bagasse were to be utilized as a fuel for energy generation.

The production of hydrogen gas can be theoretically implemented on a large scale by using the natural resources already there. As mentioned, the waste from sugarcane production, sugarcane bagasse, can be used by bacteria to produce hydrogen via fermentation and microbial electrolysis cells. Thus, biohydrogen appears to be a promising energy alternative for Cuba, given the country"s natural resources and the possibility of an independent source of fuel energy.

Hydrogen gas (H2) can be generated through the action of microbes through several different processes. These include fermentation (both light and dark), microbial electrolysis cells (MEC), and through various combinations of these processes including the use of microbial fuel cells to generate the electricity needed for MECs.

The anaerobic metabolism of glucose is a process known as glycolysis. This process yields pyruvate, which is broken down into compounds and becomes an energy source for the organisms. These energy source compounds are adenosine triphosphate (ATP) and reduced nicotinamide adenine dinucleotide (NADH) (Kalia and Purohit, 2008).

The production of hydrogen increases as the initial bagasse extract concentration also increases. However, continuous increase in concentration of bagasse extract affects the organism"s growth rate, dropping drastically the production of hydrogen (Manikkandan et al, 2009). Temperature is yet another factor that must be monitored in microbial hydrogen production. The optimum temperature that several authors have reported is 32?C. Manikkandan et al, 2009 found that for Bacillus sp., the production rate at 40?C dropped significantly due to protein deactivation. However, the use of acclimated pure or mixed cultures has had high conversion efficiencies at 37?C (Logan et al, 2002).

The time for reaction as well as the other factors affecting production depends on the specific bacteria. For example, while Bacillus sp. has a maximum hydrogen production of 0.23 mol of H2 per mol of substrate under optimized conditions at 48hr (Manikkandan et al, 2009), C. butyricum achieved maximum yield of 1.73 mol of H2 per mol of substrate, under optimized condition, in just 40 hours.

The MEC process is nonspontaneous and it requires an external source of energy to drive the electrochemical reactions. Under anaerobic conditions, applying a small amount of voltage (> 0.2 V) between the anode and the cathode drives the production of hydrogen. This process is now known as electrohydrogenesis or microbial electrolysis. The MEC is not entirely sustainable because the cell requires an external energy source in the form of electricity. However, a MFC can provide the power required by a MEC, resulting in a MEC-MFC coupled system (Sun et al., 2009; Hatzell et al., 2013).

Early experiments utilized a traditional and inexpensive design to demonstrate the concept of BESs. Characterized by its H-shape, the design consists of two bottles connected by a tube and a cation/proton exchange membrane (e.g., Nafion or Ultrex) or a salt bridge that assists the movement of protons from the anode to the cathode of the cell, while isolating the substrate (Figure 5). In the case of a MEC, a gas collection and release system accompanies the cathode. Furthermore, BES efficiency was successfully improved by increasing the size of the membrane and the surface area of the anode with the addition of graphite granules. (Logan et al, 2006, Logan et al, 2008).