Photo-biological Reactor for Organic Waste Consumption and Hydrogen Production

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Abstract

The current global economy relies on fossil fuels, therefore air pollution concentration rises every day. With a growing population and industrial development, comes an increase in energy demand, need for greater sanitary infrastructure, and an urge for minimal ecosystem damage. Many successful articles about biological hydrogen production were recently approved by major international journals, revealing it is a growing trend and a reasonably new approach for hydrogen production and waste disposal. Current researches indicate that purple non-sulfur bacteria may consume organic matter and produce hydrogen with sunlight energy contribution, on normal pressure and temperature.

Photosynthesis is critical for life on Earth but it can also be directed toward the generation of industrially useful bio-products, including hydrogen. Even though hydrogen gas is not naturally available in our environment, it is the most abundant element on the universe and a potential energy carrier. While organic wastes are normally the major portion of anthropic residues and adding the fact that, if disposed inadequately, becomes pollutant. A model is being created to predict hydrogen production by organic acid consumption, easily found on early stages of the commonly used anaerobic fermentation (Equation 5 - Figure 1- REITH, et al. 2003). Switching the methanogenic step for a photosynthetic reaction(Equation 2 - Figure 1 - REITH, et al. 2003), instead of methane, hydrogen is produced as a final product. The crucial issue of this research is using solar energy to produce hydrogen directly, a shortcut, so there would be a significant reduction in the energy input requirement.

Computational models become a strategic approach when studying biochemical reactor, and the COMSOL Multiphysics® software can drastically simplify the process of product development if used correctly. First, a zero dimension analysis for a perfectly mixed batch reactor is studied using the Chemical Reaction Engineering Module, with kinetic parameters initially taken from literature, but experimental parameters will be necessary for model validation. Primary result expected are shown on Figure 2, retrieved from a previous MATLAB® code that was developed for my final graduation project, using organic acids diluted on water as substrate. With preliminary results, the continuous transport of diluted species on a flat plate and tubular reactor will be modeled using symmetry for lower computational requirements. Combing the Heat Transfer (including solar radiation) and Fluid Flow interfaces, different physical parameters could be studied reducing the span of possibilities and requirements for experimental procedures.

Finally, simulating with COMSOL Multiphysics becomes even more helpful when modeling hydrogen usage as a fuel. Future applications could include the Batteries & Fuel Cells and AC/DC modules for an integrated project for hydrogen production and consumption, transforming residues on useful energy, contributing for renewable energy and waste disposal researches. A global approach could make the overall efficiency explicit and the all-embracing model could be used as reliable information for financial aid and investment purposes.

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Figures used in the abstract

TABLE 1 *Overview of currently known biological hydrogen production processes [16]*

Process		General reaction	Microorganisms used
1 Direct Biophotolysis		$2\ H_2O + light \rightarrow 2\ H_2 + O_2$	Microalgae
2 Photo-fermentations		$CH_3COOH + 2\ H_2O + light \rightarrow 4\ H_2 + 2\ CO_2$	Purple bacteria, Microalgae
3 Indirect biophotolysis	a	$6\ H_2O + 6\ CO_2 + light \rightarrow C_6H_{12}O_6 + 6\ O_2$	Microalgae, Cyanobacteria
	b	$C_6H_{12}O_6 + 2\ H_2O \rightarrow 4\ H_2 + 2\ CH_3COOH + 2\ CO_2$	
	c	$2\ CH_3COOH + 4\ H_2O + light \rightarrow 8\ H_2 + 4\ CO_2$	
		Overall reaction: $12\ H_2O + light \rightarrow 12\ H_2 + 6\ O_2$	
4 Water Gas Shift Reaction		$CO + H_2O \rightarrow CO_2 + H_2$	Fermentative bacteria, Photosynthetic bacteria
5 Two-Phase H_2 + CH_4 Fermentations	a	$C_6H_{12}O_6 + 2\ H_2O \rightarrow 4\ H_2 + 2\ CH_3COOH + 2\ CO_2$	Fermentative bacteria + Methanogenic bacteria
	b	$2\ CH_3COOH \rightarrow 2\ CH_4 + 2\ CO_2$	
6 High-yield Dark Fermentations		$C_6H_{12}O_6 + 6\ H_2O \rightarrow 12\ H_2 + 6\ CO_2$	Fermentative bacteria

Figure 1: Biohydrogen production methods.

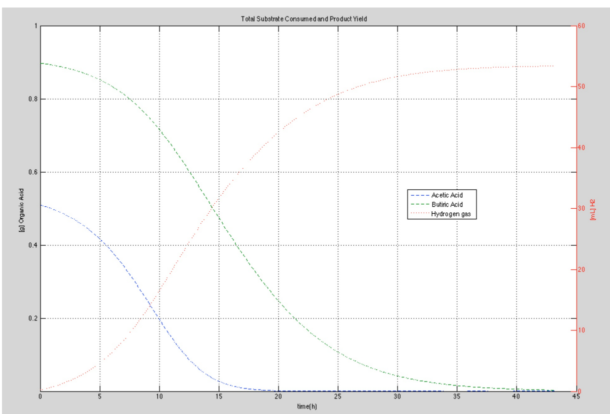

Figure 2: Substrate consumption and hydrogen production.