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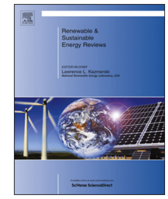

Biotechnological and bioinformatics approaches for augmentation of biohydrogen production: A review

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ABSTRACT

Biohydrogen production (BHP) from biomass is a characteristic feature of prokaryotes and is considered to be a vital source of renewable energy. It is considered as the cleanest fuel with no emanation of greenhouse gases on ignition. The major biological processes for hydrogen (H_2) production are: biophotolysis of water by algae and cyanobacteria, dark fermentation and photo-fermentation. For the past fifty years, lot of work has been carried out for understanding and improving BHP and still it has to overcome some of the serious limitations so that it becomes viable proposition. The bottlenecks include thermodynamic inefficiency, difficulty in using lignocellulosics as feed material, raw material cost and lower hydrogen yield. To overcome these major problems, the conventional approach is not enough and one has to vigorously think modern bioinformatics approaches to conquer them. The accessibility of huge sequenced genomes, functional genomics studies, the development of *in silico* models at the genome scale, metabolic pathway reconstruction, and synthetic biology approach predicts engineering strategies to enhance H_2 production in an organism. This review investigates the recent status and advancements that have been made in the area of biotechnology and bioinformatics, to understand and enhance the H_2 generation to overcome current limitations and make biohydrogen, a reality in near future.

Contents

1. Introduction

More than 95% of the world's energy demands are reliant on earth's fossil fuels, for example, coal, oil and natural gas. On the other hand, their far reaching utilization is responsible for changes

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in worldwide atmosphere created due to the emission of pollutants. The combustion of fossil fuels prompts air contamination, acid rain, expanding levels of tropospheric ozone, depletion of stratospheric ozone, the greenhouse effect and thereby global warming. Other restricting variables are that these assets are limited and unevenly distributed around the globe [1,2]. Currently, the rate of global energy consumption is in the region of 16.3 TW [3], with USA and extended EU each representing about 40% of this. Industrialization in underdeveloped and developing countries, coupled with expanding world populace will further increase the worldwide energy demand [4]. At present a cluster of conceivable fuel sources is being inspected and renewable energy resources are suggested as an alternative, which are fit for overcoming these issues. H_2 is thought to be the most promising future fuel as it is non-polluting in nature and smolders to form water, which can be further reused [5,6]. The interest for H_2 is not restricted to its usage as a source of energy, as H_2 gas is also widely used for the creation of chemicals, for the hydrogenation of fats, furthermore, is in the nourishment business for margarine creation, processing steel and for the desulfurization and reformulation of gasoline in refineries [7].

BHP plays a critical role since it is considered as the cleanest fuel with no emission of greenhouse gases on combustion. This production procedure makes utilization of microorganisms that tend to produce H_2 from lignocellulosic biomass and waste material [1,8–12]. These materials are excellent source of fermentable sugars and are present in complex form and hardly digestible [11,13,14]. Direct or indirect biophotolysis, photo-fermentation and dark fermentation methods are utilized for BHP and these techniques in detail are discussed later in the review. The low yield of H_2 by BHP methods is one of the major challenges that needs to be addressed before it can be used for industrial purpose.

Apart from wet lab experiments, *in silico* approaches like, functional genomics, genome scale metabolic engineering and flux balance analysis can be used to improve the H_2 producing capabilities (Fig. 1).

Genome-level *in silico* models provides a powerful resource for logical engineering of biological systems for enhancement in BHP. An accurate genome-scale model of an organism help us in studying the effect of genetic and environmental perturbations on it, and hence this information actuate experiments in the area of metabolic engineering [15]. Ever since the development of the first genome scale model in *Haemophilus influenzae* [16], the available high-throughput biological data have been utilized efficiently for systems level modeling approaches [15]. The modeling and construction of biological components, functions and organisms non existing in nature or redesigning existing biological systems to perform new functions is considered as Synthetic biology [17]. In this review, we discuss the utilization of biotechnological and bioinformatics approaches/techniques to improve H_2 production to overcome the current hurdles.

2. Biohydrogen production methods

Direct or indirect biophotolysis, photo-fermentation and dark fermentation methods can be used for BHP. Biophotolysis method makes use of photoautotrophic microorganisms like cyanobacteria or green microalgae that possess chlorophyll a and other pigments and has a natural capacity to capture sunlight and split water to make H_2. Pigments in photosynthetic systems, Photosystem I are capable of splitting water into protons (H^+), electrons (e^-) and O_2, and the electrons are further used to reduce a ferredoxin to produce H_2 by a hydrogenase enzyme [18–20]. One significant advantage of biophotolysis is that it is an extremely efficient conversion of solar energy to H_2. In this process, along with H_2

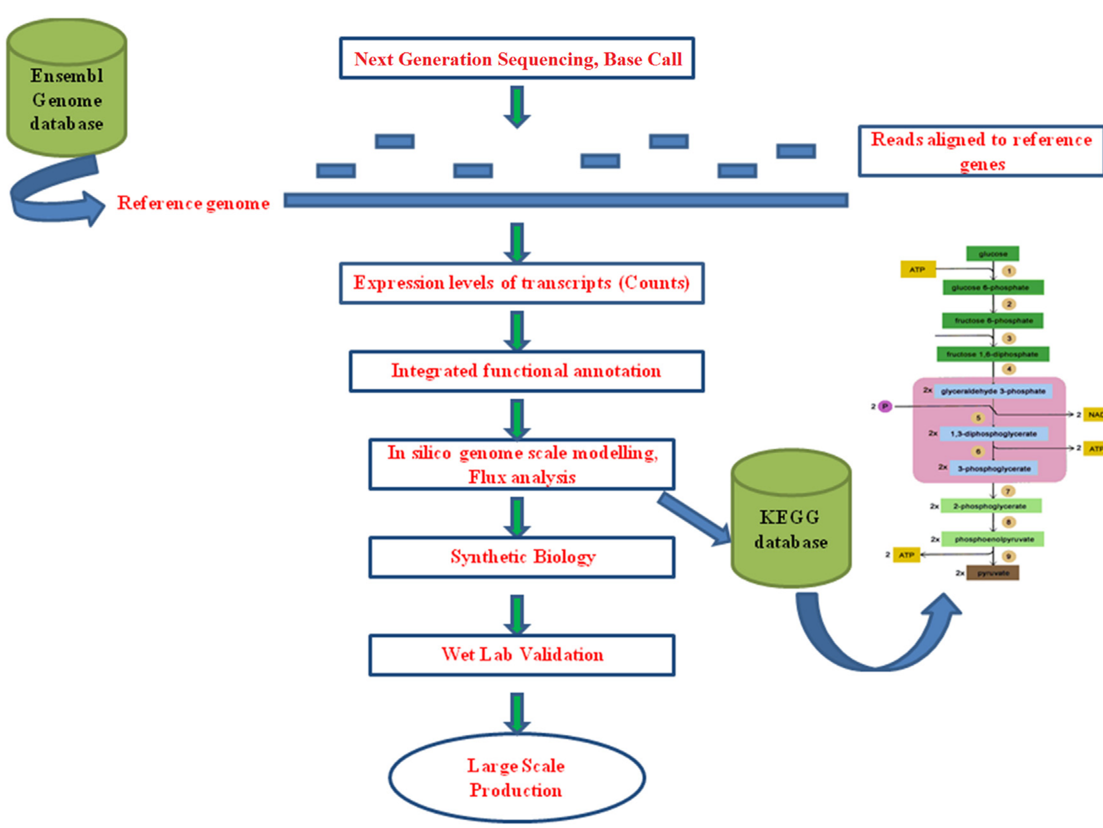

Fig. 1. Schematic representation of various approaches for augmentation of biohydrogen production.