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Review

A comprehensive review on recent biological innovations to improve biogas production, Part 1: Upstream strategies

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ABSTRACT

This study reviews the innovations and optimizations in biogas production from the biological perspective reported by recently published patents and research works. The proposed biological strategies can be categorized into three different groups, i.e., upstream, mainstream, and downstream approaches. In the first part of this review, upstream strategies, including pretreatments by fungal, microbial consortium, and enzymatic as well as some other biological methods including microaeration, composting, ensiling, and genetic and metabolic engineering are discussed in detail. The impacts of upstream strategies on biogas production as well as their potentials in further improving the biogas industry are comprehensively scrutinized. Despite their promising impacts on biogas production, such biological innovations are time-consuming and require extra equipment and facilities that should be addressed in future studies. Overall, most information on biogas production has been generated through lab-scale investigations and not by commercial plants, undermining the commercial value of these data for the right decision-making. Pilot data would be necessary for techno-economic analyses with acceptable accuracies. Therefore, the future efforts should be directed toward providing the missing data for re-engineering designs, calculations, and life cycle assessment (LCA) of the newly designed biogas plants.

Contents

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List of abbreviations

A. hydrophila *Aeromonas hydrophila*
AD Anaerobic digestion
AF Anaerobic fungi
B. licheniformis *Bacillus licheniformis*
B. subtilis *Bacillus subtilis*
C. rugose *Candida rugose*
C. subvermispora *Ceriporiopsis subvermispora*
C. vulgaris *Chlorella vulgaris*
COD Chemical oxygen demand
CoD Co-digestion
CSTR Continuously stirred-tank reactor
F. velutipe *Flammulina velutipe*
F. proliferatum *Fusarium proliferatum*
FW Food waste
G. candidum *Geotrichum candidum*
GHG Greenhouse gases
H. Hansenula *Hansenula anomala*
HRT Hydraulic retention time
L. deiliehii *Lactobacillus deiliehii*
LBR Leach bed reactor
LCFA Long chain fatty acids
M. thermophile *Myceliophthora thermophile*
MC Microbial consortium
MSW Municipal solid waste
N. fischeri *Neosartorya fischeri*
N. prasina *Nocardiopsis prasina*
OFMSW Organic fraction of municipal solid waste
OLR Organic loading rate
P. agglomerans *Pantoea agglomerans*
P. chrysosporium *Phanerochaete chrysosporium*
P. florida *Pleurotus florida*
Pl. ostreatus *Pleurotus ostreatus*
P. eryngii *Pleurotus eryngii*
S. cerevisiae *Saccharomyces cerevisiae*
S. viridosporus *Streptomyces viridosporus*
SRT Solid retention time
T. acidaminovorans *Thermanaerovibrio acidaminovorans*
T. hermosaccharolyticum *Thermoanaerobacterium hermosaccharolyticum*
T. viride *Trichoderma viride*
T.trogii *Trametes trogii*
TS Total solids
UASB Upflow Anaerobic Sludge Blanket
VFAs Volatile fatty acids
VS Volatile solid
VSS Volatile suspended solids

1. Introduction

The global population is increasing at an exponential rate, leading to unprecedented crises, among which energy security and environmental concerns (i.e., air pollution and greenhouse gases, GHG) are of prominent concerns [1,2]. Currently, about 88% of world energy demand is met by apparently economically-beneficial fossil fuels while the environmental cost associated with their widespread applications is mostly ignored [3,4]. For instance, the annual GHG missions caused by fossil fuel combustion stand around 33×10^5 tones [5]. Global warming and the resulting environmental and ecological hazards are among the primary challenges faced today as a result of extensive GHG emissions [6,7]. In response to the challenges mentioned above, efforts have been put into expanding the use of alternative sources of energy or renewable energy carriers such as biofuels (Fig. 1) [8–14].

The International Panel on Climate Change (IPCC) has forecasted that energy generation from biomass, including various types of biofuels, will stand at 50000, 75000, and 89000 TWh in 2050, 2075, and 2100, respectively [16]. Biomass could be converted into various types of renewable energy carriers such as biogas [17,18], bio-oil [19], biodiesel [20–27], bioethanol [28–30], and bioelectricity [9,31] using a wide range of physiochemical (e.g., extraction, transesterification, combustion, carbonization), thermochemical (e.g., combustion, gasification, liquefaction, pyrolysis), and biochemical (e.g., fermentation, anaerobic digestion, AD) technologies. The projections set forth by the Annual Energy Outlook 2016 stress that biofuel production would increase to about 1.0 million b/d in 2025. Whereas according to the biogas production projections, a higher value of 1.2 million b/d would be expected by 2025 [32]. Among different types of biofuels, biogas evolved from organic wastes in AD units is a promising alternative

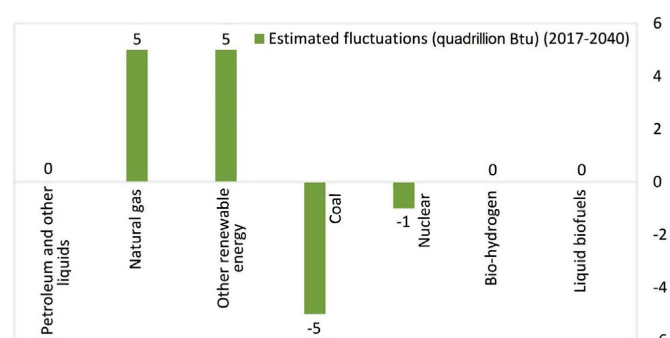

Fig. 1. Primary fluctuations in energy use by fuel from 2017 to 2040 (quadrillion Btu) [8,15].