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Review

A review of the production and applications of waste-derived volatile fatty acids

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HIGHLIGHTS

- Different types of wastes used for VFA production are reviewed.
- Important factors influencing VFA production performances are detailed.
- Various applications of waste-derived VFA are examined.
- Effects of VFA chain-length on the performances of the applications are elucidated.
- Future research needs of microbial VFA production are proposed.

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ABSTRACT

Low cost production of volatile fatty acids (VFA) from waste by acidogenic fermentation has drawn extensive research interests as VFA is a critical substrate for microorganisms involved in the production of biodegradable plastics and bioenergy, as well as those in biological nutrient removal processes. This article reviews the various wastes amenable to VFA production, the pertinent factors influencing the VFA production, and the various applications of the resulting VFA. In addition to the usual need for reasonably high concentration, a key feature for many applications is the distribution of the chain length of the VFA. Means to regulate these performance indicators are surveyed and discussed in detail.

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Abbreviations: 3HB, 3-hydroxybutyrate; 3HV, 3-hydroxyvalerate; BNR, biological nutrient removal; CE, coulombic efficiency; CSTR, continuous stirred-tank reactor; COD, chemical oxygen demand; DOC, dissolved organic carbon; FVS, filterable volatile solids; HRT, hydraulic retention time; MFC, microbial fuel cell; MSW, municipal solid waste; OLR, organic loading rate; OFMSW, organic fraction of municipal solid waste; P(3HB), poly(3-hydroxybutyrate); PD, power density; PHA, polyhydroxyalkanoates; PS, primary sludge; sCOD, soluble chemical oxygen demand; SDS, sodium dodecyl sulfate; SDBS, sodium dodecyl benzene sulfonate; SRT, solids retention time; TCOD, total chemical oxygen demand; TOC, total organic carbon; TS, total solids; TVS, total volatile solids; TSS, total suspended solids; UASB, upflow anaerobic sludge blanket; WAS, waste activated sludge; VDS, volatile dissolved solids; VFA, volatile fatty acids; VS, volatile solids; VSS, volatile suspended solids.

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1. Introduction

The rapid growth of human population and the global economy has led to massive waste generation. Proper waste management is crucial to minimize further environmental degradation and to foster the transition to a sustainable society. The conventional waste management approach is treatment-oriented, which mainly focuses on meeting environmental regulations. This approach neglects the potential of diverting the waste as feedstock for the production of value-added chemicals, as such also reducing the quantities of waste. Therefore, a more enlightened waste management approach is resource recovery, which allows simultaneous minimization of waste and generation of value-added products. Among the various possibilities of the latter, the focus of this review is the production of volatile fatty acids (VFA) from various organic wastes.

VFA are short-chain fatty acids consisting of six or fewer carbon atoms which can be distilled at atmospheric pressure [1]. These acids have a wide range of applications such as in the production of bioplastics [2], bioenergy [3,4] and the biological removal of nutrient from wastewater [5]. At present, commercial production of VFA is mostly accomplished by chemical routes [6]. However, the use of non-renewable petrochemicals as the raw materials and the increasing price of oil have renewed the interest in biological routes of VFA production [7]. In biological VFA production, pure sugars such as glucose and sucrose have been commonly employed as the main carbon source [8,9], which raises the ethical concern on the use of food to produce chemicals. This issue can be resolved by utilizing organic-rich wastes such as sludge generated from wastewater treatment plant, food waste, organic fraction of municipal solid waste and industrial wastewater for VFA production. Such transformation of waste into VFA also provides an alternative route to reduce the ever increasing amount of waste generated.

In general, the production of VFA from waste is an anaerobic process involving hydrolysis and acidogenesis (the latter is also known as acidogenic fermentation [10] or dark fermentation [11]), as illustrated in Fig. 1. In hydrolysis, complex organic polymers in waste are broken down into simpler organic monomers by the enzymes excreted from the hydrolytic microorganisms. Subsequently, acidogens ferment these monomers into mainly

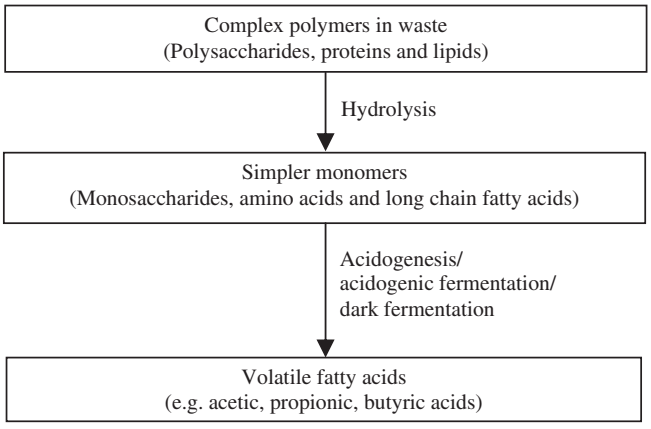

Fig. 1. Production of volatile fatty acids from waste (adapted from [12,152]).

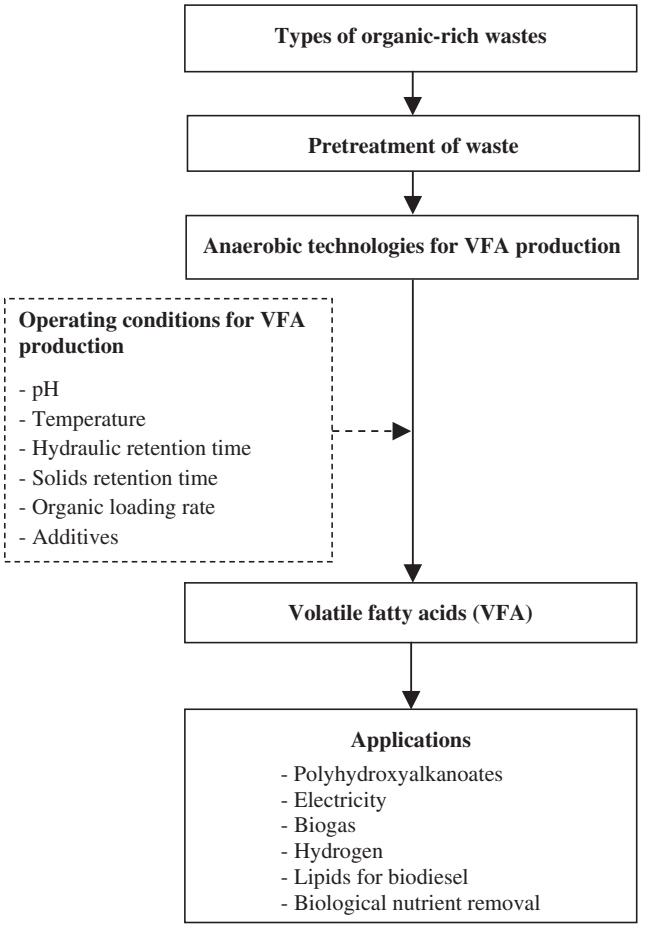

Fig. 2. Outline of the review article: production of waste-derived volatile fatty acids and their applications.