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Reviewing the anaerobic digestion of food waste for biogas production

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ABSTRACT

The uncontrolled discharge of large amounts of food waste (FW) causes severe environmental pollution in many countries. Within different possible treatment routes, anaerobic digestion (AD) of FW into biogas, is a proven and effective solution for FW treatment and valorization. The present paper reviews the characteristics of FW, the principles of AD, the process parameters, and two approaches (pretreatment and co-digestion) for enhancing AD of food waste. Among the successive digestion reactions, hydrolysis is considered to be the rate-limiting step. To enhance the performance of AD, several physical, thermo-chemical, biological or combined pretreatments are reviewed. Moreover, a promising way for improving the performance of AD is the co-digestion of FW with other organic substrates, as confirmed by numerous studies, where a higher buffer capacity and an optimum nutrient balance enhance the biogas/methane yields of the co-digestion system.

Contents

1. Introduction

1.1. Food waste (FW) generation

With the worldwide economic development and population growth, food waste is increasingly produced mainly by hotels, restaurants, families, canteens and companies. The amount of FW

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was nearly 90 million tons in China by 2010, as shown in Fig. 1. FW accounts for a large proportion in municipal solid wastes (MSW) in both of developed and developing countries, as shown in Tables 1 and 2 [1].

1.2. Characteristics of FW

According to the different eating habits, the FW composition will vary, with rice, vegetables, meat, eggs and other main components. As shown in Table 3, the total solid (TS) and volatile solid (VS) contents of FW were in the ranges of 18.1–30.9 and 17.1–26.35, respectively, indicating that water accounts for 70–80% in FW. Due to this high moisture content (MC), FW is an easily biodegradable organic substrate. Without any effective treatment measures, the disposal of FW has caused severe environmental pollution in many countries [2,3]. The traditional approaches for FW disposal were mainly landfill, incineration and aerobic composting. Whereas landfilling FW has been largely banned in many countries, incineration is energy-intensive (due to the high MC) and often creating air pollution. Both environmentally unfriendly approaches are gradually discarded. The application of FW as animal feed also bears a lot of risks since the propagation of diseases will be higher if FW is directly used as animal feed as a result of the shorter food chain. Laws are hence increasingly more severe with respect of environmental protection and to ensure food safety. Alternative methods for FW disposal are needed to tackle the waste crisis.

1.3. Principles of FW anaerobic digestion

As shown in Table 3, FW not only contains macromolecular organic matter, but also contains various trace elements. Currently, AD of FW has become an intensive field of research, since the organic matter in FW is suited for anaerobic microbial growth [6]. During the anaerobic process, organic waste is biologically degraded and converted into clean biogas [7]. According to Appels et al. [8], the biodegradation process mainly includes four steps: hydrolysis, acidogenesis, acetogenesis and methanogenesis, as shown in Fig. 2.

Differently, Molino et al. [9] pointed out that AD of organic waste can be split into three steps: hydrolysis, acidogenesis and methanogenesis.

No matter how many steps are involved in AD, the biodegradation processes of the both approaches are similar. Firstly, high molecular materials and granular organic substrates (e.g., lipids

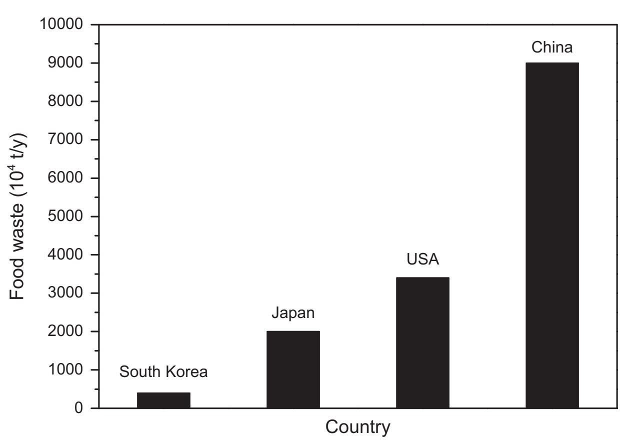

Fig. 1. The amount of FW discharged in some countries.

Table 1
Proportion of FW in MSW in China

Cities	Beijing	Shanghai	Guangzhou	Shenzhen	Nanjing	Shenyang
Percentage	37	59	57	57	45	62

Table 3
Characteristics of FW reported in literatures

Parameters	Zhang et al. [2]	Zhang et al. [3]	Zhang et al. [4]	Li et al. [5]
TS (%, w.b.)	18.1 (0.6)	23.1 (0.3)	30.90 (0.07)	24
VS (%, w.b.)	17.1 (0.6)	21.0 (0.3)	26.35 (0.14)	232
VS/TS (%)	0.94 (0.01)	90.9 (0.2)	85.30 (0.65)	94.1
pH	6.5 (0.2)	4.2 (0.2)	–	–
Carbohydrate (%, d.b.)	61.9	–	–	55.2
Protein (%, d.b.)		–	–	15
Fat (%, d.b.)	23.3 (0.45)	–	–	23.9
Oil (%, d.b.)	–	4.6 (0.5)	–	–
C (%, d.b.)	46.67	56.3 (1.1)	46.78 (1.15)	54
N (%, d.b.)	3.54	2.3 (0.3)	3.16 (0.22)	2.4
C/N	13.2	24.5 (1.1)	14.8	22.5
S (ppm, w.b.)	0.33	–	2508 (87)	8.6
P (ppm, w.b.)	1.49 (0.09)	–	–	88
Na (%, d.b.)	0.84	3.45 (0.2)	–	2.24
K (%, d.b.)	0.3	2.30 (0.04)	0.90 (0.11)	–
Ca (%, d.b.)	0.07	0.4 (0.01)	2.16 (0.29)	2.44
Mg (%, d.b.)	0.03	0.16 (0.01)	0.14 (0.01)	–
Fe (ppm, w.b.)	3.17	100 (23)	766 (402)	–
Cu (ppm, w.b.)	3.06	–	31 (1)	–
Zn (ppm, w.b.)	8.27	160 (30)	76 (22)	–
Al (ppm, w.b.)	4.31	–	1202 (396)	–
Mn (ppm, w.b.)	0.96	110 (95)	60 (30)	–
Cr (ppm, w.b.)	0.17	–	< 1	–
Ni (ppm, w.b.)	0.19	–	2 (1)	–

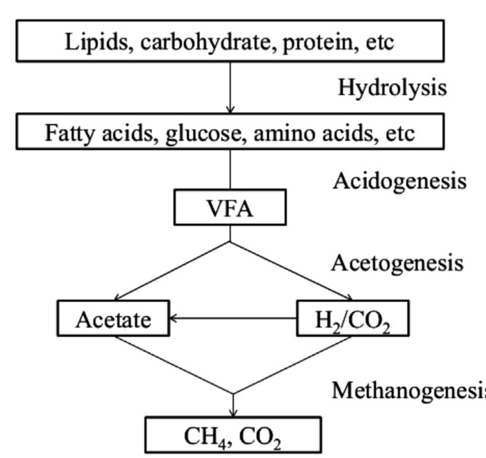

Fig. 2. Four steps in the AD of organic substrates.

Table 2
Proportion of FW in MSW in some countries

Countries	USA	England	France	Germany	Holland	Japan	South Korean	Singapore
Percentage	12	27	22	15	21	23	23	30