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Feasibility of using kitchen waste as future substrate for bioethanol production: A review

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ABSTRACT

This review highlights the utilization of kitchen wastes as substrates for bioethanol production. Kitchen wastes are commonly renewable, cheap and produced in large quantities daily. Kitchen wastes also contain a significant amount of organic matters particularly carbohydrates that can be converted into fermentable sugars for subsequent use in bioethanol fermentation. However, the advantages of kitchen wastes in biofuel production are indeed an untapped resource and poorly documented due to the challenges in the handling and disposal of kitchen wastes. Hence, a proper pretreatment and hydrolysis of the kitchen wastes by physical, chemical and biological methods is explored to increase the concentration of fermentable sugar released during the hydrolysis by enzymatic saccharification, thereby, improve the efficiency of the whole process. Furthermore, the advantages and drawbacks of each technology, challenges associated with feedstock handling and storage, government policies, and applications at commercial scale are critically discussed.

1. Introduction

In Malaysia, there are approximately 2500 t of municipal solid wastes (MSW) generated per day in major cities with an average per person of 1.2 kg/day [1] consisting mainly of fermentable organic materials and kitchen wastes (71.6%), plastics (13.3%) and papers (5.8%), which comprise 80% of the overall weight [2]. It has been recorded that Malaysians produced 33,000 t of solid waste daily in 2012, exceeding the government's projected waste production of 30,000 t daily by 2020 [3]. At present, landfill system is the only waste management option for MSW in Malaysia. In order to divert as much as possible waste from landfill, MSW are recycled. However, they are not fully recovered and recycled due to the limited source separation and lack of proper recycling activity [4]. Since plastics, papers, and glasses are widely used, they become the most common recyclable items.

The daily generation of kitchen waste is accelerated with substantial increase in volume due to rapid urbanisation, rapid growth of population and increase in food consumption rate. These organic wastes are discharged from various sources including households, restaurants and leftovers from food industries that consists of uneaten food as well as food preparation residues comprising of rice, meats, vegetables, fruits, bakery and dairy products [5]. The amount of kitchen waste is projected to increase due to the rapid economic expansion and population growth, especially in the Asian countries (Fig. 1) [6]. Asian economic giant, which is China has produced approximately $19,500\times10^4$ t/year of food waste. Meanwhile, other countries such as the United States, India, Japan, and Korea have also followed a similar trend, discarding between 624 – 3500×10^4 t/year of food waste. For instant, the developing South-eastern Asia countries including Thailand, Vietnam, and Malaysia, have generated about 440 – 712×10^4 t/year of food waste.

Kitchen waste generation is a topic concern by most countries including Malaysia. This might be due to the unpleasant odour, vermin attraction and toxic gas emission generated by the decomposed kitchen waste containing high biodegradable organic compounds [7]. The heterogeneous composition of kitchen waste causes the specific content to be extremely unpredictable. Besides, in the landfill, kitchen waste with high percentage of moisture will generate leachate and require secondary wastewater treatment system [8].

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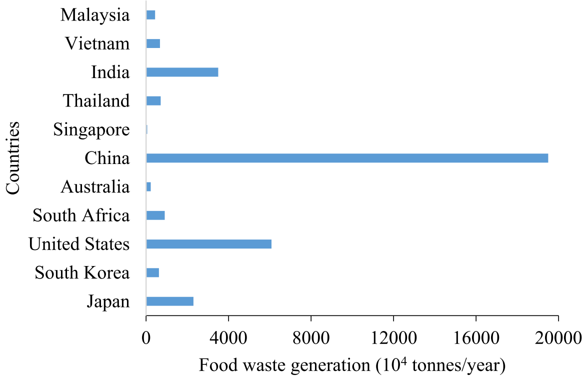

Fig. 1. : Kitchen waste generation from several countries [6].

Furthermore, kitchen wastes have also been employed as the animal feed and fertilizer. The major constraint in utilizing kitchen waste as animal feed and fertilizer is the high salt content from the traditional food culture [8]. The components of kitchen waste such as proteins, amino acids and organic acids can also be utilized as substrates and nutrients for fermentation and enzymatic conversion processes [9]. Therefore, it is imperative to overcome the stated problem by recycling method which further converts the organic fraction into valuable products.

2. General characteristics of kitchen waste

The organic fraction of kitchen waste is heterogeneous based on its composition and source. Thus, the specific content of kitchen waste can be extremely different and unpredictable in different countries [10]. Typically, the main fraction of kitchen waste consists of rice, meats, and vegetables. Kitchen waste is characterised by high organic and biodegradable materials and consists of approximately 60% carbohydrate, 20% protein and 10% lipid [11]. The composition of carbohydrate polymers (starch, cellulose and hemicellulose), proteins, lipid, fiber and other inorganic matters makes kitchen waste a promising raw material for various biotechnological processes [12]. The characteristics of kitchen waste are summarized in Table 1. The most remarkable characteristic of kitchen waste is high in moisture content and humidity with high calorific value [13]. The pH and moisture contents of kitchen waste were observed to be ranging from pH 4–6 and 70–80% (w/w), respectively (Table 1). The average total carbohydrate and protein content in the kitchen waste are 70% (w/w) and 20% (w/w), respectively.

The potential of applying kitchen waste in industry is possible through advance biotechnology engineering approaches as it could generate several added products with new value that can be recovered during downstream processes as shown in Fig. 2. Considering the complexity composition of kitchen waste, it is suggested that kitchen waste should be utilized for the production of high valuable materials such as organic acids, biodegradable plastics and enzymes. Additionally, the hydrolysis of kitchen waste might release fermentable sugars, which are amenable to fermentation by microorganisms for the production of biofuels such as ethanol, hydrogen, and methane.

3. Bioethanol production

In recent years, research have been focusing on the production of second-generation biofuels including ethanol to reduce the world reliance and dependency on the supply of fossil fuel [21,22]. Many countries such as Brazil, the United States, Japan, China and Europe are interested in producing internal biofuels due to the large incentive given to biofuel to be use as a replacement for gasoline. Such interest is mainly due to the increase in the oil prices, recognition in depletion of

Table 1
Characteristics of kitchen waste.

					Nutritional Value				Elemental analysis		
pH	Moisture Content (% w/w)	Total Solid (% w/w)	Total Volatile Suspended Solid (% w/w)	Carbon / Nitrogen (C/N)	Total Carbohydrate (%/TS)	Total Kjeldahl Nitrogen (%/TS)	Crude Fiber (%/TS)	Total Fat (%/TS)	Carbon (% w/w)	Nitrogen (% w/w)	References
4.2 ± 0.23	nd	23.19 ± 0.54	95.69 ± 1.27	31.18 ± 1.37	nd	nd	nd	nd	nd	nd	Zhai et al. [14]
nd	nd	18.81 ± 0.12	17.24 ± 0.08	18.88 ± 0.09	46.43 ± 0.32	14.97 ± 0.35	17.64 ± 0.52	30.27 ± 0.21	51.83 ± 0.27	2.75 ± 0.03	Tian et al. [15]
5.08	77.83	22.17 ± 1.57	17.87 ± 1.28	13.98	nd	16.88 ± 1.24	nd	33.82 ± 5.04	32.85	2.35	Wang et al. [16]
nd	77.39	22.61	17.9	11.5	33.28	14.71	8.61	28.85	30.25	2.63	Shen et al. [17]
4.1	82.8	17.2	16.7	17.8	nd	nd	nd	nd	50	2.8	Xiao et al. [18]
6.5 ± 0.2	nd	18.1 ± 0.6	17.1 ± 0.6	13.2 ± 0.2	nd	nd	nd	23.3 ± 0.45	46.67	3.54	Zhang et al. [19]
3.9	nd	12.9	12.5	49.9	69.3	16.1	nd	10.6	nd	nd	Zhang et al. [20]

nd not determined