Enhancement of glucose recovery from banana stem by 4-cycle enzymatic hydrolysis

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Abstract

Valorisation of banana waste into value-added products has gained an increasing interest since decades ago. To date, there is still limited information on the rational direction of banana stems, which are conventionally dumped and burnt at the field or disposed into water streams, leading to serious environmental pollution. In this work, we present a novel approach to maximise the recovery of glucose from banana stem. Initially, the effect of substrate load (1%, 3%, 5%, 7% and 9%) on the enzymatic hydrolysis by liquozyme and spirizyme was investigated. Following that, 4-cycle enzymatic hydrolysis was performed and the recovery of glucose was determined for every cycle. The results showed that the optimum substrate concentration for the enzymatic hydrolysis of the banana stem was 1% (w/v) which gave the best hydrolysis yield. Evaluation of one to five cycles of enzymatic hydrolysis showed that the highest hydrolysis yield and rate were achieved during the fourth cycle, which was 2.3-fold and 4.4-fold compared to that achieved in the first cycle.

Moreover, the glucose concentration recovered in the fourth cycle was 2.4-fold higher than that attained in the first cycle. Our results clearly showed the advantages of conducting multiple cycles of enzymatic hydrolysis of banana stems. In summary, this work presents a novel approach for maximising the glucose recovery from the banana stem where the method may also be applicable for recovering sugar from other agricultural wastes.

Keywords: Banana stem, enzymatic hydrolysis, glucose recovery.

Introduction

Banana is the second most planted fruit in Malaysia with the amount of 530,000 metric tonnes planted per year[14]. Upon the fruit harvesting, other portions of the tree such as stem, leaves and petioles, are typically left in the field. Over the years, the accumulation of banana waste has caused severe environmental pollution as the waste is mainly burnt or disposed into the water streams[8,38]. It is estimated that banana residues generated are 4-fold the amount of the fruit harvested, indicating the massive amount of waste that needs to be tackled from the banana plantation[29]. Banana stem constitutes about 75% of the total waste generated at the banana plantation sites[24,31]. It is reported that the banana stem has 49.3% cellulose, 12% hemicellulose and 13.9% lignin on an average[36]. Besides its high cellulose content, the relatively low content of lignin in the banana stem has made the banana stem an attractive source for deriving sugars which can be used for various applications.

Valorisation of banana stem for the production of various bioproducts such as sugar, ethanol and lactic acid has been reported widely in the literature[4,11,14-16,25]. Despite the numerous works published in the literature, one of the bottlenecks lies in the recovery of sugar due to the challenge of pre-treatment and hydrolysis. The aforementioned works highlighted different pre-treatment and hydrolysis strategies, most of which depended on the use of acids or bases which are deemed harsh chemicals. In addition, the chemical pre-treatment generates undesirable by-products that require an additional cost of waste disposal besides producing excessive amounts of inhibitory products which may affect the fermentation process[7].

One of the effective ways of hydrolysing cellulosic biomass such as banana stem is by enzymatic hydrolysis. Enzymatic hydrolysis, as opposed to acid hydrolysis, requires relatively moderate conditions and generates little to no harmful waste[17]. Amongst the enzymes that have been used for hydrolysing banana stem in previous works include cellulase[4, 11]. Apart from the type of enzyme, the strategy of enzymatic hydrolysis also plays an important role. Enzyme recycling is one of the options that can benefit hydrolysis due to the reuse of the enzymes where the method is efficient and is capable of producing high-target products. In a work by Awg-Adeni et al[2], 3-cycle enzymatic hydrolysis was performed for recovering glucose from sago fibre, where the method involved the recycling of enzymes from the previous cycle.

The results showed that the maximum yield after the 3-cycle enzymatic hydrolysis was significantly higher than that achieved during the first cycle. In another work, Visser et al[41] highlighted the benefits of the adoption of two-step enzymatic hydrolysis for obtaining glucose from sugarcane bagasse. Due to the limited information on the efficient enzymatic hydrolysis for extracting sugar from banana waste, mainly banana stem, research in this field is therefore very crucial.

Hence, this study aims to introduce an enhanced technique of enzymatic hydrolysis that aims to maximise glucose recovery from banana stems. Unlike the chemical pre-treatments, our strategy requires less harsh chemicals whilst