

Glucose production from potato peel waste under microwave irradiation



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ABSTRACT

Potato starch was chemically hydrolyzed to glucose using silicotungstic acid ($\text{H}_4\text{SiW}_{12}\text{O}_{40} \cdot n\text{H}_2\text{O}$, HSiW) as catalyst under microwave irradiation in a short duration (5 min). Potato starch was completely converted to glucose, levulinic acid and formic acid. The methodology was further used for the conversion of potato peel waste (PPW), a zero value waste to glucose. A glucose yield of 59 wt.% was obtained upon the microwave irradiation (15 min) of PPW. The combined use of solid acid catalyst and microwave irradiation offers a fast and green process for glucose production from starch based waste materials.

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1. Introduction

Renewable energy sources are being investigated vigorously [1]. Bioethanol is an alternative to non-renewable transportation fuels [2]. Sustainability of bioethanol production is dependent on the availability of feedstock. Starch is a vital component of agricultural and kitchen wastes which is a cheap and abundant feedstock for the production of fermentable sugars, a precursor to bioethanol. Biomass is being explored intensively as a feedstock for the production of bioethanol [3–7].

Conversion of agricultural and food wastes to fuels is attractive from economic and environmental aspects [8,9] and this has been the objective of many researchers [10–14]. Commercialization of bioethanol is dependent on the availability of the feedstock as well as the economic feasibility of the conversion. Typical challenges involved in the production of bioethanol in an economically feasible way include: (1) identifying appropriate feedstock; (2) developing suitable pretreatment methods; and (3) developing fast and efficient methods of hydrolysis for the release of glucose and the subsequent fermentation of the sugars [15–19]. Solid waste crops and kitchen wastes (potato peels) could be potential feedstock for the production of renewable energy [20,21]. Khawla et al. used

enzymatic saccharification to obtain the fermentable sugars from potato peel waste [22].

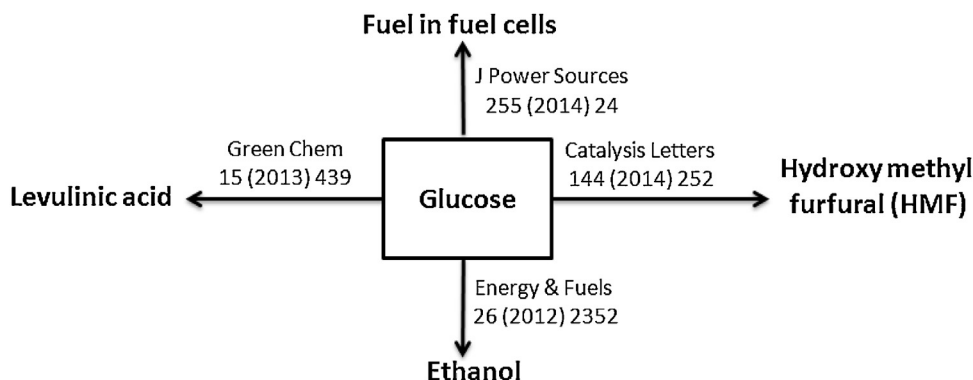
The transformation of starch into glucose is generally carried out by its hydrolysis with mineral acids or with amylase [23]. The use of mineral acids is environmentally unfriendly and the use of enzymes makes the process costlier as well as longer in terms of time. Heteropoly acids (HPA's) are environmentally friendly and reusable [24]. Tsubaki et al., reported the use of solid acid catalyst and microwave irradiation for the starch hydrolysis which is limited to corn starch [25]. Heteropoly acid (HPA) catalysts are being investigated as possible substitute to mineral acids for the hydrolysis of starch and cellulose [26]. Sonication and microwave based technologies accelerate the depolymerization of starch [27]. Thus, the focus of the current investigation is to develop a fast and environmentally friendly chemical process for the production of glucose from starch-based wastes using a HPA catalyst and microwave irradiation. The primary motivation for the synthesis of glucose lies in the fact that glucose could be subsequently converted to several fine chemicals and fuels (ethanol in particular) as depicted in Scheme 1.

2. Experimental

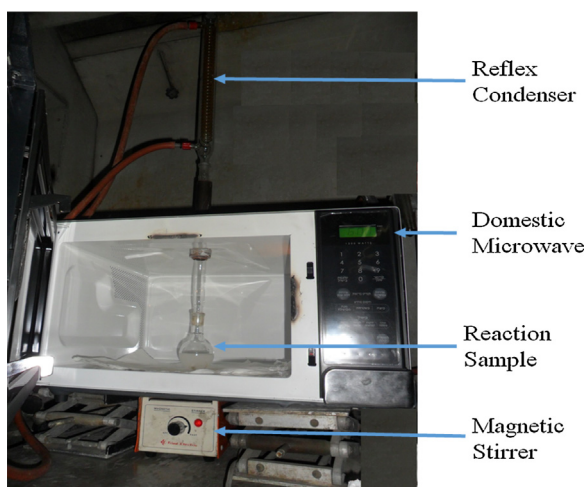
Potato peels were obtained, from our kitchen, generated as waste during cooking. All reagents were used without further purification. Double distilled water was used as a solvent. The starch hydrolysis was carried out in a domestic microwave oven

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Scheme 1. Schematic representation of potential uses of glucose.



Scheme 2. Experimental set-up used for the hydrolysis of potato peel waste.

(DMWO, SHARP R-390F) operated at 2.45 GHz in a batch mode under atmospheric pressure in the presence of air and cooling condenser attached to the reaction vessel. The output of the microwave oven was 1100 W and was operated at 100% power. The microwave oven was so modified as to have stirring provision at the bottom of the oven (depicted in Scheme 2), by replacing the turntable and the turner [26]. In addition, the reaction process is presented in the form of a movie (video 1).

Typical potato starch (99.98%, commercial sample procured from Sigma Aldrich Ltd., Israel; Product Number: S4251; CAS-No.: 9005-25-8) hydrolysis process comprise of taking a known amount of potato starch (0.1–0.5 g), catalyst (0.5–2.5 g, HSiW) and water (10–50 mL) in a round bottom flask followed by microwave irradiation (2–5 min). The reaction conditions, like the microwave irradiation time, wt./wt.% ratio of the reactant and the catalyst, were optimized so as to enhance the yield of glucose. The reaction temperature attained (109 °C) after 5 min, as a result of microwave irradiation was evaluated using a pyrometer (Fluke, 65 Infrared thermometer) just after the completion of the reaction. Experiments related to potato peel wastes deals with 20 wt.% aqueous suspensions (prepared using a blender) of potato peels. Typical hydrolysis process of potato peel waste comprises of taking 10 mL of potato peel waste suspension (20 wt.%) and 1 g HSiW catalyst and irradiating the same for different periods of time (2–15 min) in a microwave oven. The hydrolysate thus generated from starch and potato peels were analyzed by ^{13}C NMR (on a Bruker Avance DPX 300 instrument using D_2O as a solvent) to monitor the hydrolysis process and to examine the reaction products [1,27]. The catalyst (HSiW) is separated from the hydrolysate using solvent extraction

(diethyl ether) method [28]. The crystalline structural stability of HSiW after microwave irradiation was evaluated using XRD analysis (on a Bruker D8 advanced X-ray diffractometer). HPLC analysis was carried out on a Shimadzu system with a refractive index detector (RID-10A). A strong cation-exchange column (Aminex HPX-87H, 300 × 7.8 mm) was used for the chromatographic separation and quantification of various components in the hydrolysate.

3. Results and discussion

Arapoglou et al., have reported the hydrolysis of potato peel waste, in a process based on enzymes which are not reusable and long process times are generally required [9,22]. Tsubaki et al., reported the use of solid acid catalyst and microwave irradiation for the starch hydrolysis which is limited to corn starch [25]. Hernoux-Villiere et al., reported the potential of combined use of microwave-sonochemical irradiation for glucose production from potato starch but using corrosive mineral acid (H_2SO_4) as catalyst [29]. To overcome the limitations of enzymes, mineral acids, feed-stock availability, an improved process for glucose production from starch based waste materials is reported herewith.

3.1. Effect of time of microwave irradiation

The microwave irradiation time of the starch solution (0.1 g starch in 10 mL water) in the presence of the catalyst (0.5 g, HSiW) was varied from 2 to 5 min. The ^{13}C NMR Spectra of the hydrolysate obtained from the microwave irradiation of potato starch for 2, 3 and 5 min were shown in Fig. 1. The sharp and intense signals at 60.6 (C6), 69.5 (C4), 72.7 (C2), 75.7 (C3), 75.8 (C5) and 95.8 (C1 β) were typical of glucose. The peaks at 27.9 (C5), 29.1 (C2), 37.7 (C3), 177.4 (C1) and 214.2 (C4) are characteristic of levulinic acid which is a by-product from glucose conversion.

Klein et al., also observed the formation of levulinic acid along with glucose in the depolymerisation of glycogen under microwave irradiation [30]. The peak at 99.6 ppm in the ^{13}C NMR spectra of the hydrolysate is typical of unreacted starch (Fig. 1(a) and (b)). In the case of 2 min and 3 min irradiated samples, traces of unreacted starch were still observed. Complete conversion of starch to glucose is achieved after 5 min of microwave irradiation (Fig. 1(c) where no peaks typical of starch were noticed. For comparison, the ^{13}C NMR spectrum of authentic sample of starch (1 wt.%) is shown in Fig. S1. The ^{13}C NMR spectra of authentic samples of glucose, levulinic acid and formic acid (165 ppm) were shown in Fig. S2. Thus the optimum time of irradiation for the complete conversion of starch is 5 min. The details of the conversion of starch and the distribution of the products in the hydrolysate as a function of microwave irradiation time are summarized in Table S1.

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