THERMO-ACID PRETREATMENT OF STARCH BASED KITCHEN WASTE FOR ETHANOL PRODUCTION

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ABSTRACT

Recently, research on the alcoholic fermentation of kitchen waste has been accelerating for both ecological and economical reasons, primarily for ethanol use as renewable biofuel. Present work deals with the fermentative production of ethanol from different starch based kitchen waste. Kitchen waste from local students restaurant was separated by basic component as: peas, green beans, beans, rice, potato, wheat bread and corn. Thermo-acidic pretreatment of these raw materials was conducted by the addition of HCl up to pH of 1, and by autoclaving at 120^{o}C for 30 min. From the experimental result, maximum ethanol yield was obtained from wheat bread (0.11 g/g). The highest ethanol yield per starch of 0.36 g/g, which equals to 64% of the theoretical value, was obtained for peas. From the overall analysis, the examined thermo-acid pretreatment was the most efficient for hydrolysis of wheat bread, while it was least efficient for green beans. In order to enhance the efficiency of conversion of starch from kitchen waste into ethanol, pH lower than 1 is highly recommended. The results demonstrated the potential of different food waste as a promising biomass resource for the production of ethanol.

Keywords: bioethanol; kitchen waste, thermo-acid pretreatment

1. INTRODUCTION

Biomass-derived ethanol is an alternative transportation fuel which is one of the most important renewable fuels contributing to the reduction of negative environmental impacts generated by petroleum-based source of energy (Kim et al., 2011). Although sugarcane or cereal grain are the predominant feed stocks that are used for industrial ethanol production today, projected fuel demands indicate that new, alternative, low priced feed stocks are needed to reduce ethanol production costs. Kitchen waste or so called food waste is a kind of organic solid waste discharged from restaurants, cafeterias and households, and accounts for a considerable proportion of municipal solid waste in (Yan et al., 2011). Food waste is a low cost complex biomass containing carbohydrate as high as 65% of its total solid including various components such as starchy, fatty, and cellulosic materials. A portion of kitchen waste from restaurants is collected and used as animal feed. However, some of these residues are perishable and sometimes moldy. Therefore, its implementation as animal feed is a gate for the entrance of mycotoxins into the human food chain, and raises severe health problems (Ebrahimi et al., 2008). Most food residues are land filled or incinerated, resulting in ground water contamination or emission of noxious gases and dioxins (Hong et al 2011). Hence, the food waste management has been an important issue for protecting the environment as well as for conserving resources. A pretreatment is required to hydrolyze the food waste and produce monomeric sugars. The fermentable sugars then can be used as substrates for the fermentative production of ethanol. The pretreatment for biomass can be carried out in different ways such as acid hydrolysis, heat treatment, and enzymatic hydrolysis (Kim et al., 2011).

In this study, we focus on ethanol production from kitchen waste collected from dining halls from students restaurant. The present paper is the preliminary study regarding ethanol production from different kinds of starch based kitchen waste, which are always on the daily menu. Fermentation of thermo-acidic pretreated different kitchen wastes was conducted to compare the concentration of ethanol that could be produced.

2. MATERIALS and METHODS

Materials

Kitchen waste (KW)
Starch based kitchen waste from local student's restaurant was separated by basic component as: peas, green beans, beans, rice, potato, wheat bread and corn. Each KW sample was ground using the laboratory blender to obtain mash with diameter of particles smaller than 3 mm. KW samples (44.0 g dm) were poured into an Erlenmayer flask (0.5 l) and mixed with distilled water, keeping the dry matter to water ratio (hydromodule) at 1:5.

Yeast strain
Commercial pure-culture yeast *Saccharomyces cerevisiae* (Anchor WE372, Anchor Yeast, Johannesburg, South Africa) was used as a producing microorganism for ethanol fermentation. Yeast was activated by hydration in 0.1% sterile peptone prewarmed to 35^{o}C, and then inoculated into the fermentation medium (0.25g/kg).

Methods

Thermo-acidic pretreatment
Thermo-acidic pretreatment of the KW mash samples was conducted by the addition of 1 M HCl up to pH of 1, and by autoclaving at 120^{o}C for 30 min. Afterwards, the pretreated KW were cooled at room temperature and neutralized with 1 M NaOH up to pH 5, in order to obtain optimal pH of the fermentation medium.

Iodine Test
In order to test if starch hydrolysis was complete the iodine test which is a qualitative estimate of starches present was conducted. Three drops of iodine were added to 1 ml of each neutralized KW sample to test for starches. The presence of starches is denoted by a blue color due to the starch-iodine complex. Dextrins present produce a brown color.

Ethanol fermentation
After inoculation the flasks were fixed on a rotary shaker (GFL, Germany, Type 3015) at shaking frequency 120 rpm and shaking diameter 30 mm, and placed in a thermostat at 30^{o}C. During the fermentation, the weight loss due to CO_2 release was measured at various time intervals from the beginning of each fermentation batch. At the end of each batch fermented liquid was distilled.

Analytical methods
Dry mass, starch and protein content of the KW samples were estimated as per the standard AOAC methods. The ethanol concentration was determined based on the density of alcohol distillate at 20 ^{o}C by pycnometer method (AOAC methods, 2000). Electrical resistivity, conductivity and total dissolved solids content (TDS, g/l) of fermentation medium were determined using laboratory multi-parameter analyzer Consort C863 (Consort, Belgium).

Fermentation parameters
The ethanol yield ($Y_{p/kw}$, g/g) was calculated as grams of ethanol (*P*) produced per gram of kitchen waste dry matter (*DM* g). The ethanol yield per starch ($Y_{p/s}$, g/g) was calculated as grams of produced ethanol (*P*) per gram of initial starch (S_u). The fermentation efficiency ($E_{p/s}$, %) was calculated as percentage $Y_{p/s}$ of the maximal theoretical ethanol yield per starch.

3. RESULTS AND DISCUSSION

The quality parameters of KW are shown in Table 1. As expected, the highest value of dry matter content was obtained for wheat bread (68.2%), while for other KW from cooked meals were more than twice lower. KW on the basis of cooked potato had dry matter content of only 16,4%, suggesting that high ethanol concentration from this raw material can not be expected. The highest starch (88.5% dm) and protein (28.9% dm) content in KW dry matter was obtained for corn. The peas had the lower starch content (31.2% dm), while potato was the poorest in protein content (6.2% dm).

Table 1 Quality parameters of kitchen waste

Kitchen waste	Dry mater (%)	Moisture (%)	Starch (% dm)	Protein (% dm)
Peas	19,3	80,7	32,1	21,8
Green beans	12,8	87,2	42,1	20,1
Rice	37,6	62,4	64,6	7,3
Wheat bred	68,2	31,8	69,9	13,2
Beans	25,4	74,6	48,1	24,1
Potato	16,4	83,6	74,9	6,2
Corn	25,3	74,7	88,5	28,9

The results of iodine test lead to the conclusion that the hydrolysis of starch from all examined KW samples to fermentable sugars was not complete, but was partly accomplished by the thermo-acidic pretreatment. Incomplete hydrolysis could be due to many factors including time of autoclaving, temperature and pH. In order to enhance the efficiency of starch hydrolysis, $pH<1$ can be one simple possibility. In conclusion, breaking down the starch to fermentable sugars was a critical step. It is well known that the shape, size and physicochemical characteristics of starch granules are particular to each plant species. Hence, the efficiency of starch hydrolysis was different for each kind of examined KW.

TDS are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water. The most common chemical constituents are usually cations calcium, magnesium, sodium and potassium and the an-ions carbonate, bicarbonate, chloride, sulfate and, nitrate which are found in substrates (Basha et al., 2008). Table 2. depicts total dissolved solids content and electrical resistivity of KW samples after thermo-acidic pretreatment and neutralization. As shown, highest TDS concentration was found in fermentation substrate based on peas (11.2 g/l), while lowest was for Corn (4.53 g/l). Electrical conductivity of substrates is directly related to the concentration of dissolved ionized solids in the substrates.

Table 2 Total dissolved solids content and electrical resistivity of KW samples after thermo-acidic pretreatment and neutralization

Kitchen waste	Total dissolved solids TDS (g/l)	Electrical resistivity (Ω/cm)
Peas	11,12	51
Green beans	8,18	64
Rice	7,07	78
Beans	7,7	72
Wheat bred	8,83	63
Potato	7,83	71
Corn	4,53	119

Table 3 summarizes the fermentation parameters obtained for different starch based KW. Based on the results shown in Table 3 KW can be considered as convenient raw materials for ethanol production. Under these experimental conditions, maximum ethanol yield was obtained from wheat bread (0.11 g/g), while minimum was obtained from green beans (0.02 g/g). However, ethanol yield per starch in the substrate was highest for peas (0.36 g/g), while it was lowest for corn (0.08 g/g). Although initial starch content in peas was the lowest of all examined KW (Table 1), its conversion to ethanol was highest (64%). On the other hand corn based KW had highest initial starch content, but its conversion to ethanol was only 13%. On the basis of observed differences it can be surmised that applied thermo-acidic pretreatment was most efficient for peas starch hydrolysis, while corn starch hydrolysis was quite poor as a consequence of physicochemical characteristics of starch granules. Experimental results showed that breaking down the starch to fermentable sugars was a critical step.

Table 3 Fermentation parameters obtained for different starch based KW

Kitchen waste	Ethanol yield $Y_{p/kw}$ (g/g)	Ethanol yield per starch $Y_{p/s}$ (g/g)	Fermetnation efficiency $E_{p/s}$ (%)
Peas	0,07	0,36	64
Green beans	0,02	0,09	16
Rice	0,03	0,10	17
Beans	0,06	0,16	27
Wheat bred	0,11	0,27	48
Potato	0,08	0,18	32
Corn	0,04	0,08	13

Because of the low initial content of starch in the fermentation substrates and high water content, low ethanol concentrations were achieved in conducted experiments. However, taking into consideration significant process parameters such as ethanol yield and fermentation efficiency it can be concluded that higher ethanol could be produced in the fermentation step by increasing the initial dry mass and consequently starch content in the fermentation medium. In this way, ethanol can be produced inexpensively using a KW feedstock that is otherwise thrown away. Results presented here confirmed the potential of different starch based food waste as a biomass resource for the production of ethanol.

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