Desalination 293 (2012) 112–117

Contents lists available at SciVerse ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Pretreatment technology for suspended solids and oil removal in an ethanol fermentation broth from food waste separated by pervaporation process

Wenyu Zhang [a], Hongzhi Ma [a,*], Qunhui Wang [a], Fangni Zhao [a], Zeyi Xiao [b]

[a] Department of Environmental Engineering, University of Science and Technology Beijing, Beijing 100083, China
[b] School of Chemical Engineering, Sichuan University, Chengdu,Sichuan 610065, China

ARTICLE INFO

Article history:
Received 6 November 2011
Received in revised form 15 February 2012
Accepted 4 March 2012
Available online 29 March 2012

Keywords:
Ethanol fermentation broth
Food waste
Pervaporation
Flocculation–filtration

ABSTRACT

Ethanol fermentation from food waste decreases pollution and optimizes waste utilization. However, the high-energy consumption involved in the distilling process hinders the industrial application of ethanol fermentation. In the present study, pervaporation was adopted to resolve such a shortcoming. A flocculation–filtration unit was used for the treatment of the fermentation broth. The purpose was to decrease the amount of suspended solids (SS) and oil, which affected the pervaporation membrane used for ethanol separation from food waste broth. Seven kinds of flocculants at three pH levels were adopted to screen the best type and corresponding dosage. Then, a mixture of fiber-ball and quartz sand was used to treat the residue oil and SS. Considering the higher flux of the filtration process, 500 mg/L sodium alginate in a raw fermentation broth was considered the best choice. After treatment, 94.74% of SS and 98.60% of oil in the fermentation liquid were removed. The effluent quality contained the desirable qualities of the inlet water in the pervaporation step.

1. Introduction

In recent years, the fermentative production of ethanol from renewable resources has received more attention because of the increasing shortage of petroleum [1]. Compared with other renewable energy resources, fuel ethanol has been meticulously investigated around the world because of its simple production process and absence of greenhouse gas emissions. The main drawbacks for its application lied in cost for raw materials and ethanol separation process.

Food waste is a kind of municipal refuse that contains high moisture and organic compound, this has been utilized as an ideal substrate for resource utilization [2–4]. Ethanol fermentation from food waste has been studied over the past several years [5,6]. This method could not only treat waste, but can also yield clean fuel, which is beneficial for the environment [7]. Compared with other substrates, food waste fermentation liquor contains not only ethanol, sugars, and salts, but also high contents of oil and suspended solids (SS). The effects of these materials on separation and how to reduce such bad effect were worth studying.

Besides traditional distillation process, pervaporation is adopted as a kind of new separation process in ethanol fermentation. It is a membrane separation process that exploits differences in vapor pressure as the driving force for separation. This process is a well-established tool for the recovering components from an aqueous phase or vice versa [8–11]. The advantages of pervaporation not only include high activity, low energy consumption, and environmental benefaction, but also could obtain ethanol with high purity because the ethanol was liquefied from the vapor, which is beneficial for its further utilization. As other studies have shown, a combination of pervaporation and distillation improves the efficiency of fuel ethanol production [12], which supplies more possibility to the application in large-scale industry.

There has some reports on ethanol separation by pervaporation with the substrates such as starch, glucose, and cellulose [13,14]. However, the utilization of food waste was not the focus. Ethanol fermentation liquid from food waste contained some salts, oil and sugar. Salts and sugars may increase the membrane selectivity, whereas SS can form on a membrane to decrease the total flux in a continuous membrane permeation system [10,15,16]. Although the impact of oil has not yet been reported, we recognize that oil adhered to the surface of a membrane may affect the dissolving and diffusing process of ethanol in that membrane. As a result, the membrane flux is decreased. Moreover, this kind of decrease is different from the one that is caused by fermentation substrates or their by-products, it's irreversible, there would be lasting damage to the membrane. The pollution on the membrane will decrease its service life, and increase the cost for membrane in large-scale application. Therefore, effective fermentation liquor management is required.

Traditional SS and oil reduction processes are utilized in sewage treatment, but there exists limited information on the applications of these processes in a fermentation broth. Flocculation is regarded as one of most effective methods for SS and oil removal [17,18]. Different kinds of flocculants, such as polyacrylamide (PAM), gelatin, and polyaluminum chloride (PAC), have varied operational conditions. Therefore, the suitable choice for SS reduction in fermentation liquid from food

* Corresponding author. Fax: +86 10 62332778.
E-mail addresses: Wangqh59@sina.com (Q. Wang), mhz527@sina.com (H. Ma).

0011-9164/$ – see front matter
doi:10.1016/j.desal.2012.03.004

waste, the impact of such a process on ethanol production, and the pervaporation process are worth investigating. Filtering is another traditional technology widely applied in water treatment processes. This technology has an upstanding effect on oil and SS removal. Zhou et al. used double-layer filter of fiber ball and sand to treat kaoline soliquoid, the removal efficiencies of particles larger than 10 μm could reach nearly 100% [19].

At present, studies on wastewater are frequently conducted at home and abroad [20,21], because wastewater treatment has entered a stage of commercialization. Nevertheless, such applications in fermentation broths are few, which is worth studying. The experience in utilization of flocculation and filter will provide valuable information in our study to perform pretreatment for ethanol fermentation liquid from food waste. The proper choice for flocculants and corresponding operation process, the effect on SS and oil removal and impact on ethanol concentration would be studied. Furthermore, the remnants of oil and SS would be treated by filter process, how the system would interfere with the pervaporation process would be studied in this study.

The suitable pretreatment would help establish the pervaporation system for ethanol separation from food waste fermentation liquid, this would be of great importance for ethanol fermentation industry in consideration of energy consumption and cost reduction.

In the current study, flocculation and filtration will be applied in removing oil and SS. The proper treatment choice and corresponding operation parameters, as well as the impact on pervaporation, will be also studied.

2. Experiments

2.1. Preparation of food waste fermentation broth

The food waste used in the present study was collected from the dining halls of the University of Science and Technology, Beijing, China. About 100 g of smashed food waste was mixed with 50 mL of water in a conical bottle. Dry yeast (Angel Yeast Company, Hubei Province, China) for ethanol production was added into the culture media with a 0.1% (g/g wet mass) inoculum size and glucoamylase (100 U/g wet mass). After 48 h, the anaerobic culture was under 35 °C. Corresponding ethanol fermentation processes from food waste could be seen in our previous studies [22,23].

As shown in Fig. 1, the obtained fermentation broth was squeezed using a gauze (Yongfeng, 36×100YDS), flocculated, and then filtered by a fiberball-sand filter. After these separation steps, the food waste fermentation broth was fed into the pervaporation system. To reduce the environmental impact, the fermentation residue and filter cake made up of flocs produced in the flocculation stage were set aside for solid biomass fuels. The contents of these fuels will be investigated in our future works. The residual liquid was reused as water for the fermentation.

Table 1 shows the characteristics of the feed solution used in the present study. The feed solution contained many components, such as SS, oil, organic acids, and residual amounts of reducing sugars and salts. Considering that only oil and SS have devastating impacts on a membrane [15,16], the removal percentage of oil and SS, along with the ethanol loss rate, was used as the evaluation parameters.

2.2. Materials

The polydimethyl-siloxane pervaporation membranes used were supplied by the School of Chemical Engineering, Sichuan University. They are a kind of polydimethyl-siloxane (PDMS) membrane on polyamide (PA) support, tetraethoxy-silane (TEOS) was used as cross-linkers, and the degree of cross-linking was 2%. The thickness of the dense silicone rubber skin layer and support layer was 8 μm and 120 μm, respectively. Corresponding membrane production process and basic characteristics were mentioned in one of the author's previous study [16]. All the reagents used were analytical grade. The flocculants used are shown in Table 2. The flocculants were all provided by the Sinopharm Chemical Reagent Co., Ltd. (China). The filter candle (Ø30×200 mm) was made of synthetic glass. The fiber-ball filter media and quartz sand were supplied by the Gongyi City Yimin Water Purification Material Co., Ltd. (China).

2.3. Experimental methods

Polyelectrolyte flocculants with different charges and molecular weights were received from the Sinopharm Chemical Reagent Beijing Co., Ltd. (Table 1).

The flocculation experiments were performed in a 250 mL flask. First, the pH of the fermentation broth was adjusted using 10% HCl or NaOH. A desired dose of the flocculant was then added into the flask. The mixture was agitated by an electronic stirrer at 500 rpm for 5 min and left to settle for 20 min. Subsequently, the sample was taken for analysis. The ethanol loss rate (E, %) was calculated using the following formula:

$$E = (M_1 – M_2)/M_1 \quad (1)$$

where M_1 and M_2 denote the ethanol quality in the untreated and treated fermented liquids, respectively.

The filter experiments adopted a synthetic glass filter candle(Ø30×200 mm) filled with a fiber-ball filter media on the top half and with a quartz sand in the lower half. The flocculated broth was delivered into the filter from the top at a uniform speed by a feed pump.

The membrane module was a circular flat-plate pervaporation cell made of stainless steel having a membrane area of 0.024 m^2. For support, the membrane was spread on a porous metal disk, which was sandwiched between an up-cover and a down-cover. The system is shown schematically in Fig. 2. All the runs were conducted at 50 °C with a downstream pressure of 1×10^3 Pa for 3 h, the feed flow velocity was controlled at around 100 L/h.

2.4. Analytical methods

The oil contents of the fermentation broth were analyzed using the petroleum ether extraction test. The SS contents were determined using the gravimetric method. Ethanol was quantified by gas liquid chromatography (Flame Ionization Detector, GC16 Shimadzu, Kyoto)

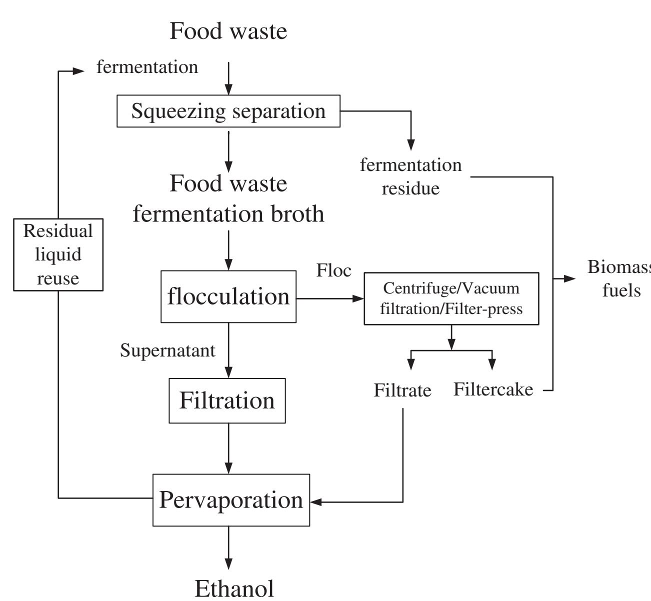

Fig. 1. Ethanol formation from food waste.