Journal of the Taiwan Institute of Chemical Engineers 64 (2016) 142–145

Contents lists available at ScienceDirect

Journal of the Taiwan Institute of Chemical Engineers

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

Continuous electrochemical removal of salts from Korean food wastes

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ARTICLE INFO

Article history:
Received 30 September 2015
Revised 7 January 2016
Accepted 5 April 2016
Available online 13 May 2016

Keywords:
Salts
Food wastes
Electrokinetics
Experimental design
Composts

ABSTRACT

In this study, we developed a new electrochemical process to remove the salts from food wastes. The primary removal mechanisms are washing and electromigration. The screw speed and current were selected as the primary factors influencing the removal of salts. An experimental design was applied in order to determine the optimum conditions for the removal of salts and 82.7% of the salts were removed under some of these conditions. Based on the continuous operation of the apparatus, the criteria for the removal of salts in the food composts could be achieved.

1. Introduction

In Korea, use as animal feed and/or composting are the most common choices for the treatment of food wastes. In 2011, approximately 13,537 tons of food wastes were being generated daily; more than 94% of these food wastes were recycled into animal feed, compost or other forms. Even though the production of food wastes decreased slightly after 2008, it still accounts for 28.7% of all Korean wastes generated [1]. In order to recycle Korean food wastes into compost and animal feed, the high salt content related to food fermentation needs to be lowered to an appropriate level [2–6].

In order to address this problem in Korean food wastes, Baek *et al.* suggested that an electrochemical method could remove more than 90% of the salts from fermented food compost within 36 h [2]. In addition, they reported that less than 9% of the calcium was removed due to differences in relative ionic mobility [7]. Several researchers have also reported that the electrokinetic process could be used to remove various ions from soil, sediment, or sewage sludge [8–13]. Although it is possible to electrochemically remove salts from food wastes or food composts, the technique has previously been conducted in a batch apparatus [2,7]. Considering the current levels of production of food wastes, the capacity needs be improved. Batch operation requires a huge storage unit, as the residence time in the batch reactor is greater than 24 h. Therefore, a new continuous process is needed for the practical application of electrochemical salt removal. In this study, we designed a new continuous apparatus that was operated on a full scale in order to remove salts from the food wastes.

2. Materials and methods

For continuous operation of the electrochemical process, we designed a screw conveyor-type apparatus. The screw conveyor acted as an anode and the outside of the pitch in the screw conveyor was wrapped with a stainless screen with an opening size of 5.0 mm. The opening size could change the electrical current density which could control the migration of salts. The gap between the pitch and screen was 3 mm, and the screen prevented crushed food wastes from coming out of the screw conveyor. The other important role of the screen was to act as a cathode. Therefore, sodium ions could be transported into the main tank through the screen. The screw conveyor was located in the center of the main tank, which was 78 cm in diameter and 164 cm in length, and approximately 75% of the main tank was filled with tap water. All of the components were made of stainless steel in order to prevent corrosion (Fig. 1). Electrical polarization and chlorine gas could accelerate corrosion of screw (anode). Even though other inert materials including dimensionally stable anode could be used for anode, but stainless steel was used because of easy processing. Crushed food wastes were introduced into the main tank using a mono-pump

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http://dx.doi.org/10.1016/j.jtice.2016.04.001
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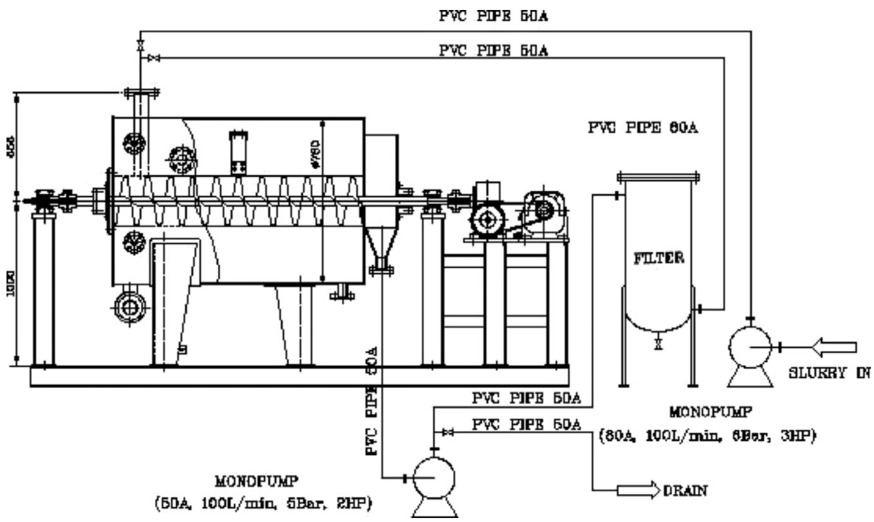

Fig. 1. Design and dimension of continuous electrochemical desalting apparatus.

Table 1
Experimental design and results.

Exp. no.	Original variables		Coded variables		Y^c
	Screw speed (rpm)	Current (A)	X_1^a	X_2^b	(%)
1	4	10	−1	−1	38.15
2	4	70	−1	1	51.74
3	10	10	1	−1	68.30
4	10	70	1	1	75.42
5	4	40	−1	0	44.38
6	10	40	1	0	86.66
7	7	10	0	−1	46.28
8	7	70	0	1	90.39
9	5	40	−0.667	0	60.43
10	20	40	4.333	0	53.71
11	5	10	−0.667	−1	42.47
12	5	70	−0.667	1	74.62
13	20	10	4.333	−1	60.60
14	20	70	4.333	1	37.74
15	7	40	0	0	63.05

a: $X_1 = \frac{[RPM-7]}{3}$.
b: $X_2 = \frac{[Current-40]}{30}$.
c: Y is the removal of salt (%).

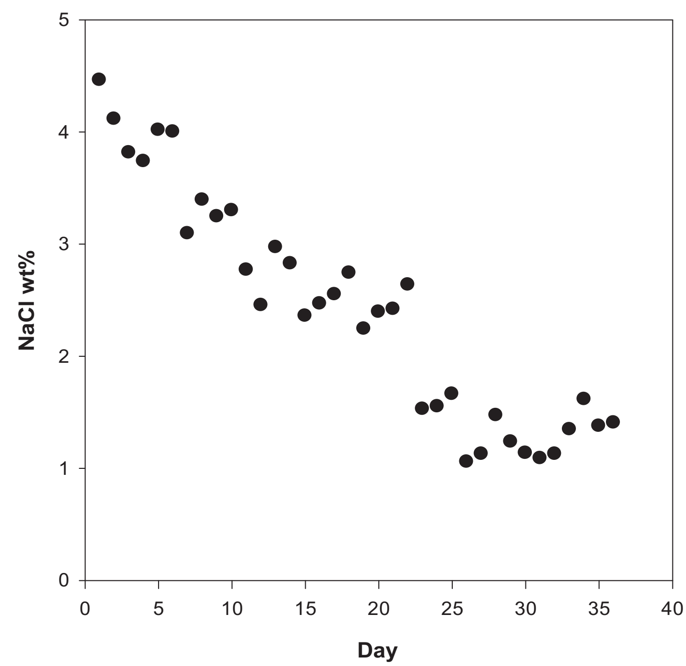

Fig. 2. Time course of salt contents in food wastes during experimental period.

and the treated food wastes were discharged by a pump. The final discharged food wastes were filtered and the water was recycled into the reactor. This apparatus was installed in existing composting plants, and the treated food wastes were then composted.

The experimental parameters were developed using a 2-factor central composite design in the coded units [7,14,15]. This allowed the influence of each factor and their interactions to be taken into consideration (Table 1). A model was fitted to the experimental data using SAS statistical software (ver. 6.12). The obtained model is as follows:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_{12}X_1X_2 + a_{11}X_1^2 + a_{22}X_2^2$$

where Y is the measured response for each test, a_1, and a_2 are the linear coefficients, a_{12} is an interactive coefficient, a_{11} and a_{22} are the quadratic coefficients, and X_1 and X_2 are also coded independent variables. In this study, the response surface was the removal of salts (%) and the independent variables were the screw speed and the applied current. The screw speed determined the residence time of food wastes in the reactor and the applied current provided the driving force for the extraction or removal of the salts from food wastes.

For the analysis of the salts, dried food wastes were extracted using 10 M of nitric acid at a solid to liquid ratio of 1–15 for 4 h. These conditions could extract exactly the same amount of sodium as the method proposed by Baek *et al.* using a microwave digestion apparatus [2].

3. Results and discussion

The salt content in food wastes varies based upon food type and therefore should be measured daily. In this study, we measured the salt contents 3 times per day and we used the average value. The food wastes were collected and transported to composting plants, and then they were crushed. The time course of initial salts contents decreased gradually (Fig. 2). During the summer, the salt content is low, because a lot of seasonal fruits and vegetables are consumed that do not contain high amounts of salt in comparison to the other traditional Korean foods, such as kimchi. The experiments started at the end of June. Therefore, the salt