SAÜ Fen Bil Der 20. Cilt, 2. Sayı, s. 185-191, 2016

Effect of operational parameters on ultrasonic treatment of baker's yeast effluent

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13.10.2015 Geliş/Received, 16.01.2016 Kabul/Accepted

ABSTRACT

In this study, ultrasound was employed to remove color and chemical oxygen demand (COD) from baker's yeast effluent. An ultrasonic homogenizator with 20kHz frequency was used for this purpose. The effect of operational parameters such as ultrasonic power, pulsed cycle, volume of wastewater and dilution ratio (wastewater volume/distilled water volume) was investigated. It was observed that decolorization increased with increasing ultrasonic power and with decreasing wastewater volume. The results show that there was no significant effect of pulsed cycle and an optimum dilution ratio was ¼ on decolorization of baker's yeast effluent. There was no change on COD value at the studied conditions.

Keywords: baker's yeast effluent, chemical oxygen demand, decolorization, ultrasound

Maya endüstrisi atıksuyunun ultrasonik arıtılmasında işletme parametrelerinin etkisi

ÖZ

Bu çalışmada, maya endüstrisi atıksuyunun renk ve kimyasal oksijen ihtiyacı (KOİ) giderimi için ultrases kullanılmıştır. Bu amaçla 20kHz frekansta ultrasonik homojenizatör kullanılmıştır. Ultrasonik güç, vuruş döngüsü, atıksu hacmi, seyreltme oranı (atıksu hacmi/distile su hacmi) gibi parametreler incelenmiştir. Renk gideriminin ultrasonik güç artarken ve atıksu hacmi azalırken arttığı gözlenmiştir. Sonuçlar maya endüstrisi atıksuyunun renk gideriminde vuruş döngüsünün önemli etkisinin olmadığını göstermiştir. Renk gideriminde optimum seyreltme oranı ¼'dür. Çalışılan koşullarda KOİ değerlerinde değişiklik olmamıştır.

Anahtar Kelimeler: kimyasal oksijen ihtiyacı, maya endüstrisi atıksuyu, renk giderimi, ultrases

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1. INTRODUCTION

Wastewater produced after industrial processes includes different organic compounds. These organic compounds may pollute the environment and give permanent damage to living species due to harmful properties such as toxicities, cancers and mutagen effects. Biological treatment may not be enough to degrade these harmful organic compounds. So that advanced oxidation methods can be used to treat industrial wastewater. Free radicals comprises by the application of advanced oxidation methods. These free radicals, especially ·OH decomposes the organic compounds into water, carbon dioxide and smaller molecules [1].

Fermentation industries such as the production of baker's yeast and distilleries use molasses as a raw material [2,3]. Colored compounds in molasses are called as melanoidins [4]. Wastewater contains molasses is specified by dark brown colour and high organic loading due to the presence of melanoidins. Melanoidins are resistant to biological treatment [5]. So that, adequate treatment is imperative before discharging of molasses wastewater.

Several treatment processes have been used in decolorization of molasses wastewater. Among them are ozonation [6-8], fenton oxidation [4,5,9-11], electrocoagulation [2-12], ultraviolet oxidation [13,14], adsorption [15,16] and ultrasonic irradiation [17-19].

The usage of ultrasonic irradiation to degradate organic pollutants in water increases due to undesirable effects in the water environment [20]. The human ear can not hear sounds above 16kHz. These sounds called as ultrasound. Ultrasonic irradiation of organic compounds in wastewater has some advantages. It is safe and clean method, there is no generation of secondary pollutants [1].

Ultrasound waves consists of compression and expansion (rarefaction) cycles. If there is enough great negative acoustic pressure during rarefaction cycle, cavities are created in the liquid. Cavities grow until they reach a critical size than cavities collapse. High temperature and pressure is obtained when the cavity collapse [1]. Under these conditions, water molecules are splited into radicals such as ·H and ·OH radicals. These generated radicals join with each other to constitute new molecules and radicals, or diffuse into a bulk liquid to react with organic pollutants [20].

In baker's yeast industry, biological treatment is used to treat wastewater and values of regulations provided. But limit values pull down day by day. So alternative treatment methods must be studied. In literature, treatment of baker's yeast effluent have been studied by using different methods such as coagulation [9-11], Fenton oxidation [4], electrocoagulation [2-12]. However, no study on ultrasonic treatment of baker's yeast effluent has been previously reported. In the studies done by Sangave and Pandit [17,18] and Sangave et al. [19], ultrasonic treatment of distillery wastewater contains molasses has been investigated. Experiments have been done using an ultrasonic bath in their study.

The purpose of this study is to remove color and COD from the baker's yeast effluent using ultrasound. The effects of ultrasonic power, volume of wastewater, dilution ratio and pulsed cycle were investigated on the ultrasonic treatment of baker's yeast effluent.

2. EXPERIMENTAL

2.1. Materials

The baker's yeast wastewater used in this study was supplied from Baker's yeast factory located in North of Turkey. The wastewater was collected before biological treatment and stored in refrigarator at 4°C. The wastewater was taken from the factory perodically in three or four weeks. The characteristics of wastewater used in this study are given in Table 1. Distilled water was used throughout this study.

Table 1. Characterization of baker's yeast wastewater used in the study

Parameter	**Value**
Absorbance at 400nm	0.3 – 0.4
pH	6
COD	5400mg/L

2.2. Experimental set up and apparatus

Ultrasonic irradiation was introduced using a probe type processor. It was supplied from Bandelin (HD2200). Its operating frequency is 20kHz and power is 200W. Absorbance of the wastewater was measured by using a spectrophotometer of Hach-Lange DR 2400. COD of the wastewater was measured using Hach DR 2400 spectrophotometer and Hach COD reactor. Instructions for the Hach higher range test were followed.

A schematic drawing of the ultrasonic reaction system is given in Fig.1. Wastewater was filtered using blue ribbon filter paper (Schleicher and Schuell) and it was diluted with distilled water before use. The dilution ratio was ¼ except for the effect of dilution ratio experiments. The reactor used in this study was a cyclindirical glass vessel with 500ml volume. This reactor was filled with diluted wastewater. Then ultrasonic probe was placed in the center of the reactor. The distance from probe to bottom of the reactor was 3cm. An experiment took 60 minute and all the experiments were repeated minimum 3 times. The samples were taken from the reaction mixture periodically and centrifuged at 4000rpm for 10 min to remove any suspended particles. After that, absorbance of the sample was recorded using spectrophotometer. Absorbance measurement was done at 400nm wavelength.

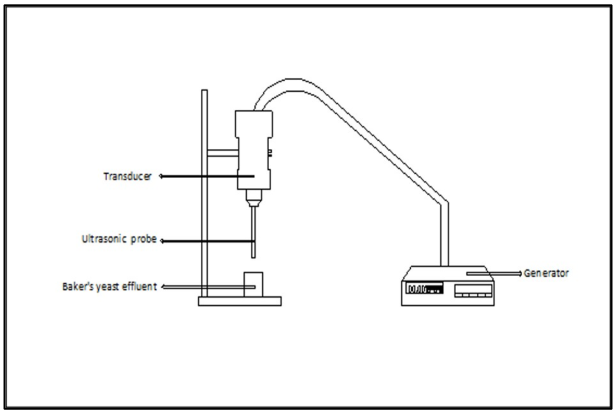

Fig.1. Schematic diagram of the ultrasonic reaction system

The percentage of decolorization of the wastewater was calculated as below:
Decolorization,

$$\% = (A_0-A)/A_0 *100 \quad (1)$$

where A_0 is initial absorbance of the sample, A is absorbance of the sample at any time.

To measure COD, 2ml sample was placed into the special vial containing dichromate solution, then it was heated in COD reactor at the desired temperature and time. After cooling the vial, COD of the sample was recorded using spectrophotometer.

In this study, there was no temperature control in any of the experiments. pH of the wastewater was the same as initial pH value (pH 6) during the ultrasonic treatment, so that there was no pH adjustment during the reaction time.

3. RESULTS AND DISCUSSIONS

3.1. Effect of ultrasonic power

To investigate the power effect on ultrasonic treatment of baker's yeast effluent, three different powers, 50, 80 and 110W were studied. Fig.2 shows these results.

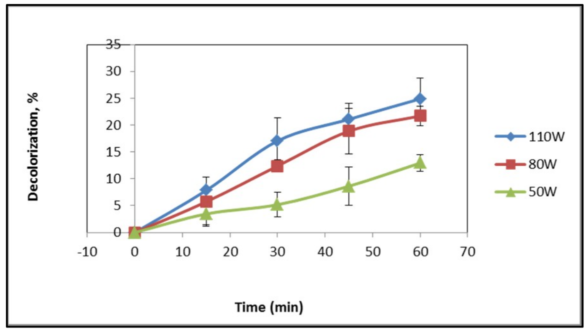

Fig. 2. Effect of ultrasonic power on decolorization of baker's yeast effluent (volume=500mL, dilution ratio=1/4, pulsed cycle=30%)

Ultrasonic energy is dissipated in the reaction liquid, so that reaction temperature increases with the ultrasonic irradiation time. In the present study, experiments started at ambient temperature about 20°C and temperature was gradually increased. Wastewater temperature was not contolled by any external mechanism. In our previous study, uncontrolled temperature for 500ml diluted wastewater gave better results than controlled temperature for ultrasonic treatment of baker's yeast effluent. Experiments started at ambient temperature and solution temperature reached 40°C at the end of 1 hour for 500ml wastewater volume [21]. If the increase in temperature has a positive effect on decolorization, the cooling water would not needed to hold temperature constant and there is no operation cost for cooling water [22]. So, in this study uncontrolled temperature was used. Similar results have been reported in ultrasonic treatment of distillery wastewater [17,18] and ultrasonic degradation of 2:4:6 trichlorophenol [23].

According to Fig.2, decolorization rate of baker's yeast effluent increases with increasing power. As it is known, when the power is increased at the same reactor area, ultrasound intensity increases. There is an inverse relationship between ultasound intensity and collapse pressure. For a single cavity, collapse pressure decreases with increasing ultrasound intensity. On the other hand, the number of cavities generated increases, so that total energy released (number of cavities*collapse pressure of a single cavity) during the collapse of cavities increases [24]. According to Merouani et. al. [25] the transmittance of ultrasonic energy into the reactor increases with increasing power. Because of this energy, the collapse of bubbles takes place more quickly and the number of cavitation bubbles increase. As a result, formation of OH radicals into the reaction mixture increases. In another study, Dükkancı and Gündüz [20] studied sonochemical degradation of butyric acid at different ultrasonic powers; 4, 8 and 31W. It was observed that as ultrasonic power increased, degradation of butyric acid increased. Xi et. al. [26] have studied the effect of ultrasonic power on degradation of m-xylene. After 60 min. of ultrasonic irradiation time, degradation rate increased with increasing ultrasonic power. The energy of cavitation increases with increasing ultrasonic power, so the quantity of cavitation bubbles and radicals grow.

3.2. Effect of wastewater volume

To investigate effect of wastewater volume, experiments were performed with 250, 375 and 500mL. As shown from Fig.3, decolorization decreases with increasing wastewater volume at the end of 60 min reaction time. When the liquid volume increases power density decreases. Power density is defined as quantity of power dissipated per unit volume of the medium. The degradation ratio increases with increasing power density of the equipment. If similar power is applied to lower volume of the reaction liquid, number of generated cavities increases, so that higher degradation rate is provided [27].

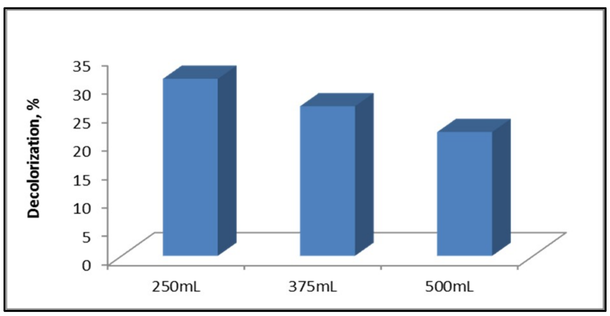

Fig.3. Effect of wastewater volume on decolorization of baker's yeast effluent at the end of 60min reaction time (dilution ratio=1/4, power=80W, pulsed cycle=30%)

3.3. Effect of dilution ratio

Figure 4 presents the effect of dilution ratio for ultrasonic decolorization of baker's yeast effluent. Dilution ratio shows wastewater volume/distilled water volume ratio. As seen from Fig. 4, decolorization of baker's yeast effluent first increased with decreasing dilution ratio from 1/5.7 to ¼, then decreases with the decrease of dilution ratio from ¼ to 1/1.5. Maximum decolorization is obtained at ¼ dilution ratio.

According to Gogate et.al [27], the consumption of free radicals occurs in two ways. In the first way free radicals attack the pollutants resulting in degradation. In the second way free radicals combine with each other to form H_2O_2. There is no enough free radicals at lower initial concentration because of the free radical recombination. There is a limiting concentration up to which destruction can be obtained with the use of ultrasound with a significant destruction rate.

The effect of initial concentation on ultrasonic decomposition of various pollutants was examined in the literature. According to some studies sonolytic degradation rate inversely proportional to the initial concentration of pollutant. It means sonolytic degradation rate decreases with increasing initial concentration [20,26,28-31]. On the other hand, a number of intermediate products increases with increasing initial concentration and these compounds inhibit degradation [31].

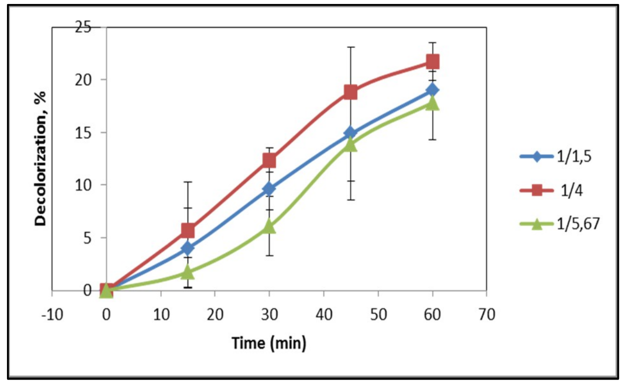

Fig.4. Effect of wastewater dilution ratio on decolorization of baker's yeast effluent (volume=500mL, power=80W, pulsed cycle=30%)

3.4. Effect of pulsed cycle (duty cycle)

Pulsed cycle (duty cycle) indicates the pulsed mode; it is divided in active and passive intervals. If cycle is 10%, it means active interval time is 0.1sec, passive interval time is 0.9sec.

To examine the effect of pulsed cycle, experiments were done at 30%, 50% and 70%. Fig.5 presents the effect of pulsed cycle on ultrasonic decolorization of baker's yeast effluent. According to Fig. 5, there is no significant difference between the pulsed cycles at the end of one hour. All pulsed cycles studied have similar behaviour. However, no clear explanation could be provided. Mechanism of effect of pulsed cycle on baker's yeast effluent needed to be researched.

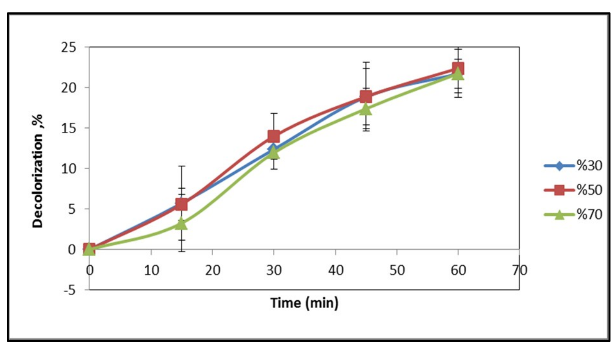

Fig.5. Effect of pulsed cycle on decolorization of baker's yeast effluent (volume= 500mL, power=80W, dilution ratio=1/4)

In literature, Qiao et. al. [32], investigated the effect of duty cycle on the ultrasonic treatment of caffeic acid and sinapic acid. According to their results, there was no significant concentration change with changing duty cycle.

3.5. COD removal

During the experiments the COD of baker's yeast effluent were measured. Fig.6 shows the results. As shown from Fig. 6, there is no decrease in COD value. In the present study, real wastewater was used. It contains different compounds coming from process. Ultrasonic degradation does not completed due to complex structure of the effluent.

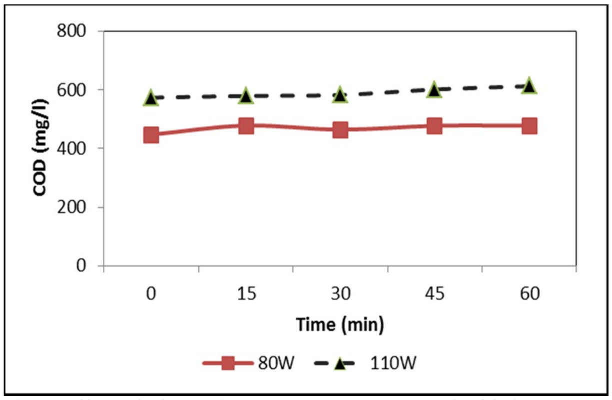

Fig.6. Effect of ultrasonic power on COD removal of baker's yeast effluent (volume= 500mL, dilution ratio=1/4, pulsed cycle=30%)

Baker's yeast industry uses molasses as a raw material. Molasses contains coloured compounds called melanoidins. The generation of melanoidins involves a lot of sequential and parellel reactions becoming between amino acids and carbohydrates. These reactions are known as Maillard reaction [4-7]. During the Maillard reactions, several pyrolysis products are produced [3].

There are similar results in literature. Sangave and Pandit [17,18] have been investigated ultrasonic treatment of the distillery effluent. If the wastewater used in the studies is a real wastewater, ultrasonic irradiation causes generation of great numbers of products due to complex structure of the effluent. It is difficult to identify these products. Low frequency of ultrasound caused degradation of the pollutant molecules in to smaller compounds rather than complete degradation reaction.

4. CONCLUSIONS

In this study, ultrasonic treatment of baker's yeast effluent was studied. The effect of various parameters such as: ultrasonic power, wastewater volume, dilution ratio and pulsed cycle were investigated. The decolorization rate increased with increasing ultrasonic power. However decolorization of baker's yeast effluent increased with decreasing wastewater volume at the end of one hour. Maximum decolorization was obtained at ¼ dilution rate. The effect of pulsed cycle on the decolorization rate was insignificant. There was no COD removal at the studied conditions.

However, the obtained decolorization for baker's yeast effluent is not high at the studied conditions. Combination of ultrasonic irradiation with other advanced oxidation methods such as ozonation, ultraviolet irradiation may give better results than ultrasonic irradiation alone. Ultrasonic irradiation can be used as pre-treatment step before biological treatment to increase decolorization of baker's yeast effluent.

ACKNOWLEDGEMENTS

The authors thank to Hitit University for their financial support of this project under contract of MUH.03.13.002.

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