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Sonoelectrolytic Disinfection Treatment in Aqueous Medium

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Abstract

Today there are many different methodologies applied to the treatment of industrial processes and its effluents or for water supply. The sonication and electrolysis are known by their efficiency in disinfection of effluents, but presenting different results for each kind of test organism. The previous knowledge of biology favors the isolation of determined groups in processes of disinfection. This research analyzed the efficiency and selectivity of sonoelectrolysis, using both electrolysis and sonication in a single treatment, applied for disinfection of suspensions containing *Saccharomyces cerevisiae* or *Escherichia coli*.

Keywords: electrolysis, sonication, sonoelectrolysis, water disinfection

1. Introduction

Disinfection uses no chemicals or chemicals that aims to inactivate microorganisms, but does not eliminate all forms of life (Di Bernardo, 2005; Pelczar et al., 1997). The disinfection techniques for water treatment generally include ozonation, chlorination, ultraviolet irradiation and filtration (Joyce et al., 2001; Pelczar et al., 1997, Mason et al., 2001). However, alternative methods that allow the disinfection of water may help in treatment and decrease the use of chlorine, one of the most widely used disinfectant in water treatment plants.

Sonication has the power to derail the microbial growth due to the onset of acoustic cavitation bubbles in the cell (Pitt and Ross 2003). Cavitation is the formation of microscopic gas bubbles, which expand to collapse, could reach enough energy to disrupt biological membranes and also change the molecular makeup of the original liquid (Dehghani, 2005). The effect of sonication is being studied in biofilms formed on implants, which is a big problem because of the difficulty of antibiotics to penetrate the biofilm matrix (Monsen et al., 2009). Sonication is also an alternative method for disinfection of water, proposed by Joyce et al. (2003) and Phull et al. (1997) and a pre-treatment effluent for subsequent biodegradation (Joyce et al., 2001; Sangave and Pandit, 2004; Phull et al., 1997).

Besides the use of sonication in water treatment and medicine, they are also applied to the use in industrial processes, which are affected by contamination from microorganisms. There are reports that the sonication is effective in non-viability of microbial cells present in sugar cane juice, such as bacteria *Leuconostoc mesenteroidese* (Caliari et al., 2004).

Lima et al. (1999) showed that the form of cane cultivation led to a selected range of bacteria, some of those resistant to antibiotics. In addition, Lima et al. (1999) isolated bacteria of natural environments, founding 82 strains of bacteria in 16 genera, and divided into 35 separate species, among them 13% of Pseudomonas (Lima et al., 1999).

According to Wood et al. (1997) the sonication may be a viable alternative to sugar-alcohol

mills bacterial control, but continued use may decrease the production of alcohol.

Despite the high power of sonication for disinfecting was recommend its use in conjunction with other techniques. It is known that the electrolytic process produces highly oxidizing or reducing species by passing electric current through the electrodes immersed in the solution, so that the cellular machinery of microorganisms may be affected (Matsunaga et al., 1984). However, other authors believe that the cells are killed physically by the wave of high-voltage pulse. In this context, Tokuda and Nakanishi (1995) demonstrated the growth inhibition of *E. coli* by applying a current of 0.33 A, increasing inhibition as the electric current increases (Tokuda and Nakanishi 1995).

Otenio et al. (2008) used electrolytic process in water treatment for the removal of heterotrophic bacteria, total and fecal coliforms in untreated water (Otenio et al., 2008).

For the treatment of effluents, electrolysis can be considered a pre-treatment, because changes in molecules during the process can facilitate the biodegradation of recalcitrant compounds (De Angelis et al., 1998).

The sonication and electrolysis are promising methods to control and microbial degradation of organic compounds (Lorimer et al., 2000).

This study aims to evaluate the effect of electrolysis, sonication and sonoeletrolysis in water treatment in the presence of *Escherichia coli* or *Saccharomyces cerevisiae*.

2. Methodology

A sonoelectrolytic cell (Figure 1) was used for the study of killing *Escherichia coli* CCT 1454 and *Saccharomyces cerevisiae* (Fleischmann Royal®). The sonoelectrolytic cell consisted in a glass beaker with 1000 mL capacity, containing a suspension with one of the test organisms. This suspension was kept under agitation by a magnetic bar. The electrodes were two titanium bars (44.84 cm^2 each) covered by a mixture of titanium and ruthenium oxides, according to Beer (1965). For the electrolysis it was used a DC Power supply (Dawer FCC - 3005D), and the sonication system was the Unique model Disruptor, that consisted of a stainless steel tip which emitted ultrasound waves of 19 kHz, and it was put on the surface of the liquid (Figure 1). In order to avoid the formation of non-homogeneous regions, it was used a phase inverter timer of T & S Equipamentos Eletrônicos, that changed the polarity of the electrodes each 30 seconds. The sonoelectrolytic cell was kept in constant temperature of 25 ℃ in order to avoid the warming caused by the sonication system.

The test organisms (*S. cerevisiae* or *E. coli*) were inoculated in a sodium sulfate solution (0.08 $mol.L^{-1}$) previously sterilized, thus forming the suspension ready for treatment. After, this suspension was exposed to the sonoelectrolytic cell to the followings treatments: 80 W sonication, 2.00 A electrolysis and sonoelectrolysis (80 W sonication with 2.00 A electrolysis). It was assumed the treatment times of: 0, 9, 18, 27, 36, 45 e 54 minutes. Current density was of 0.022 A cm^{-2}.

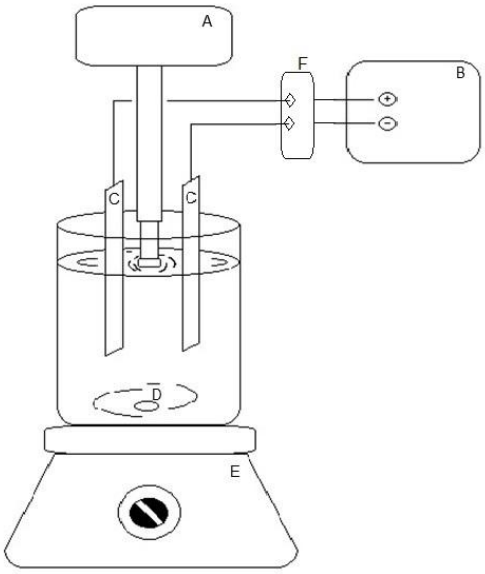

Figure 1. Scheme of sonoelectrolytic cell. A: sonication system; B: power supply; C: electrodes; D: magnetic bar; E: magnetic shaker; F: phase inverter timer.

The suspension containing *E. coli* was made with addition of an inoculum in 600 mL of sodium sulfate solution (0.08 mol.L^{-1}), obtaining 107 cells per mL, while the suspension of *S. cerevisiae* was prepared using previously centrifuged cells in 600 mL of sodium sulfate solution (0.08 mol.L^{-1}), obtaining 108 cells per mL. After the treatment, the number of survivor microorganisms was measured.

For the *E. coli* treatments it was done the counting of forming colony units (FCUs) in petri dishes by surface spreading. It was inoculated 1 mL of treated suspension in agar, and incubated in 28 ℃ for 24 h, and after this period it was done the counting of FCUs. For *S. cerevisiae* suspensions the samples of each treatment were homogenized and stained with erythrosine, an indicator for dead cells. The cells were counted using a Neubauer chamber. All counts were made in duplicate.

3. Results and Discussion

The electrolytic process was the most efficient way to inviability the cells of both test organisms (Figure 2 and 3). After 9 minutes, treatment using sonication showed survival of *E. coli* about 10% of the initial value, being close to the efficiency provided by the electrolytic treatment, but maximum reduction was observed only in time of 27 minutes (Figure 2). At 27 minutes of sonication, there was complete inviability for *E. coli*. However, cells of *S. cerevisiae* were not completely unviable (Figure 2 and 3). *S. cerevisiae* cells are yeasts that have a thick cellulosic wall, resulting in a greater sonic impact resistance and pH variations.

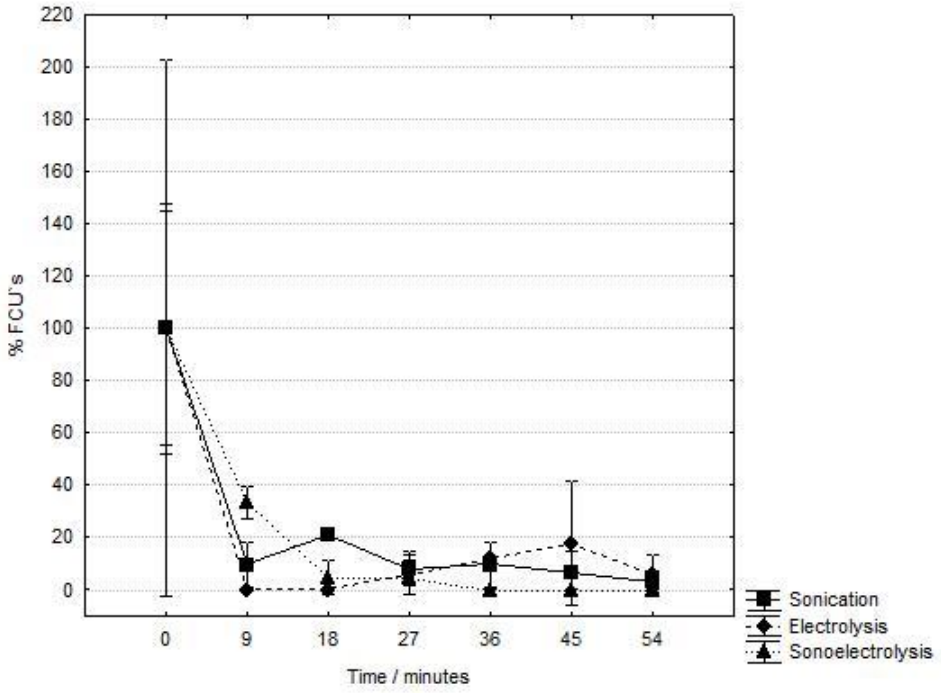

Figure 2. Inviability of *E. coli* by sonication, electrolysis and sonoelectrolysis treatment in the time.

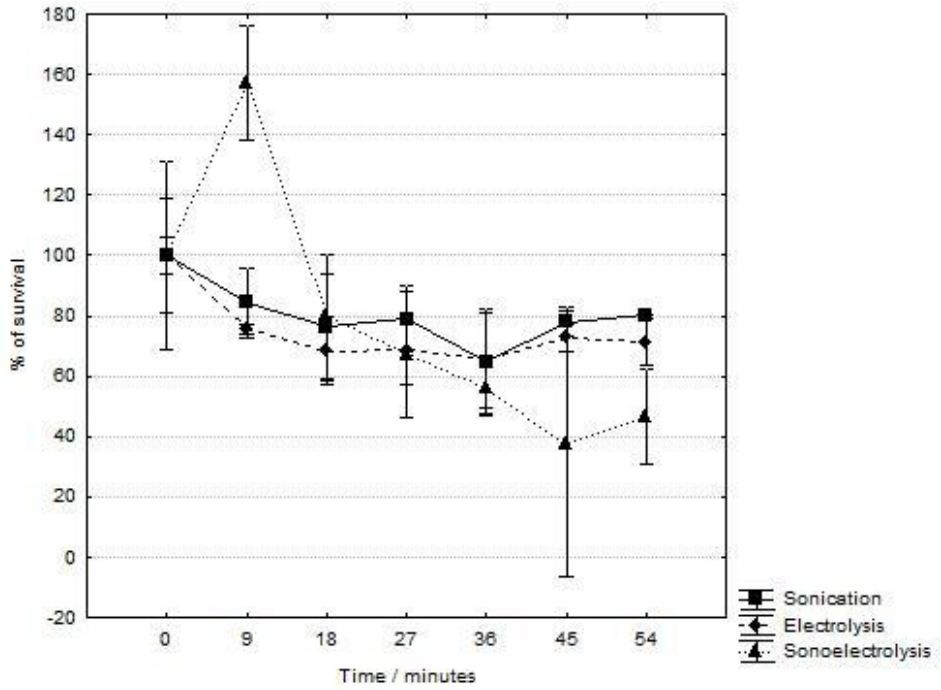

Figure 3. Inviability of *S. cerevisiae* by sonication, electrolysis and sonoelectrolysis treatment in the time.

According to Monsen et al. (2009), gram-negative bacteria, such as *E. coli*, are more sensitive to sonication in comparison to the gram-positive bacteria (Monsen et al., 2009). Thus; the fact that *E. coli* was unviable at the time of 27 minutes does not imply a generalization of this time and treatment to the inviabilization for all bacteria.

The sonoelectrolysis caused the unviable of both test organisms used, but with greater effect to *E. coli* (Figure 2) and, according to Joyce et al. (2001) the electrolysis is more efficient if agitation of the solution occurs (Joyce et al., 2001).

The realization of sonoelectrolysis showed at 9 minutes a decreasing of 50% in the survival of *E. coli* cells, and the maximum reduction was achieved in 18 minutes of treatment application (Figure 2). The sonoelectrolytic treatment for *S. cerevisiae* was more effective than other treatments after 27 minutes, with a lower survival rate, about 68% (Figure 3). Sonoelectrolytic treatment reached in 54 minutes a survival rate close to 54% (Figure 3).

The greater efficiency of inviability of *E. coli* was obtained by electrolytic treatment in 9 minutes, followed to sonoelectrolysis by 18 minutes and last 27 minutes for the sonication, according to Figure 2. The combination of the two methods, which is the sonoelectrolysis, did not show an improvement in the effect of inviability of *E. coli* compared to electrolysis. After 18 minutes of treatment using cells of *S. cerevisiae*, the decay of the electrolysis had the highest number of viable cells compared to sonoelectrolysis and sonication.

4. Conclusions

The sonoelectrolysis caused the non-viability of both microorganisms used. *E. coli* inviability was almost complete long before the *S. cerevisiae*, possibly due to greater resistance of the yeast cell wall.

The difference between the cell non-viability of the bacteria and yeast allow us to propose the electrolysis treatment and sonication as sonoelectrolysis selectively controlling contaminants in water and wastewater, as well as in industrial processes using the *S. cerevisiae*.

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