ANALYSIS OF THE OPERATING CONDITIONS OF A WASTEWATER TREATMENT PLANT TO DETERMINE THE INFLUENCE ON THE PRODUCTION OF BIOPOLYESTERS

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ABSTRACT

In this work, the influence of the operating conditions of an activated sludge reactor of a mixed plant or crop in the accumulation of polyhydroxyalkanoates (PHA) was analyzed. The purpose of this analysis is to identify the optimal conditions with which this type of reactor should operate so that there is a greater accumulation of polyhydroxyalkanoates, the production of these through mixed cultures contributes to the reduction of production costs since they are generated from a renewable substrate and low cost.

In order to achieve this analysis, the GPS-X software was used, which allows us to simulate the entire wastewater treatment process, for this particular case only the influent of the reactor, the activated sludge reactor and the effluent itself are modeled. It allowed us to use different concentrations of organic loading with which various PHA accumulation scenarios were generated, the activated sludge model 3 (ASM3) was defined with which the energy reserve models are described. It is important to remember that polyhydroxyalkanoates accumulate intracellularly in the form of granules under stress conditions, this means that they are limited to a micronutrient such as nitrogen, phosphorus, sulfur, among others, and require a substrate which allows them to accumulate Energy.

The model used is matrix notation in which 14 variables are involved and 12 processes of heterotrophic and autotrophic bacteria are carried out, this notation generates a differential equation that explains the process and allows us to analyze the desired variable. The concentration of organic matter was analyzed since at a higher concentration of this is the accumulation of polyhydroxyalkanoates, the results obtained for each of the concentrations of organic loading are discussed and a comparison of them is made to better understand how they affect the operating conditions the production of the PHA.

Keywords: Biopolymers, mixed culture, accumulation, model.

1 INTRODUCTION

Currently the environmental field is very important due to the effects produced by global climate change generated by man. One of the main sources of pollution is the use of plastics. These are the results after being used generally end up in landfills, generating the contamination of the underground aquifers by the infiltration of toxic additives. Therefore, the need to look for new methods and biodegradable materials has arisen.

It has tried to solve the problem of the accumulation of plastics in the environment, use as incineration, recycling and recycling, however these solutions are effective and there are disadvantages; During the composition process too, much time is required for degradation (Gonzalez García et al., 2013).

Biopolymers represent a friendly solution to the environment, since these are totally biodegradable and biocompatible, this means that it adapts to any living system, its degradation time is approximately two months. The main disadvantage of these is their high production cost (Valero-Valdivieso et al., 2013).

Polyhydroxyalkanoates (PHA) are biopolymers synthesized intracellularly by some microorganisms as a carbon and energy reserve. Once these are extracted from the cell, they have physical properties very similar to petroleum-based plastics, with the advantage that they are biodegradable. These have been analyzed in
recent years as they can be produced through biotechnological processes, including biological reactors of wastewater treatment plants (WWTP), in order to replace synthetic plastics.

The main disadvantage of the PHA is the high production costs, since these biotechnological processes are generally based on the use of pure crops, increasing the costs derived from the cost of the carbon source, and the associated equipment and costs necessary to control the operation of said processes.

The use of the organic matter present in the wastewater, as a raw material for the production of bioplastics can contribute to reduce production costs, since the microorganisms of the biological reactors of the WWTP are capable of producing PHA. This paper analyzes the conditions under which these bioplastics have been produced, as well as the production yield, in order to subsequently look for the optimal conditions of the operating parameters of the WWTP that maximize PHA production.

This analysis is important since, by optimizing the production of bioplastics, costs could be lowered, which would allow these processes to escalate and reduce contamination by plastics at the same time that pollutants are removed from the wastewater in the WWTP.

2 BACKGROUND

The use of renewable raw materials for the creation of biodegradable plastics such as polyhydroxyalkanoates (PHA) and bacterial poly-3-hydroxybutyrate (PHB), has generated great research interest considering the nature of petroleum-based plastics, due to the decrease in fossil fuel reserves and emissions of greenhouse gases (Sharma & Bajaj, 2015).

The polyhydroxyalkanoates are polyesters produced by prokaryotic microbes as intracellular storage materials (Figure 1), which can be extracted and then formulated and processed for the production of plastic. Depending on the length of the chain, the PHA could be thermoplastic polyesters, elastomers or even adhesive resins composed of various R-hydroxyalkanoic acids that can be produced by numerous microorganisms. Alternatively, the PHA accumulated in the biomass could be used to improve the production of volatile fatty acids, hydrogen and/or methane in anaerobic digestion processes. (Rodríguez-Perez et al., 2018).

A large variety of diverse PHA monomer compositions have been described, as well as their perspectives for future applications in which high biodegradability or biocompatibility is required. (Chanprateep, 2010). The bioconversion of PHAs in microbial cells is affected by both growth environments and feeding systems. The carbon source of the substrate is of utmost importance for the production of PHA in the various growth environments (Możejko-Ciesielska & Kiewisz, 2016) The PHA types are defined by the length of the repeating monomer carbon chain attached to the 3-hydroxyalkanoate molecule, such as short (C3-C5), medium (C6-C14) and long (C15-plus). The type of chain will depend on the microorganism that is making the accumulation of the PHAs as well as the substrate used (Burniol-figols, Varrone, Balzer, et al., 2018).

The physical properties of bioplastics will depend on their monomeric composition, since these biopolymers were first discovered to refer to them as lipid compounds and are water-insoluble polyesters, most of these polymers are partially crystalline and their thermal properties and mechanicals are usually represented in terms of the transition temperature (Tg) or the melting temperature (Tm) (Burniol-figols et al., 2018).

The polymers of each cut are commonly thermoplastic polymers, this means that at relatively high temperatures becomes elastic or deformable, melts when heated and becomes rigid in a glass transition state when cooled sufficiently, its properties are gradually changing if they melt and mold several times as their links weaken. As for medium chain polymers they are called elastomers (Guerra-Blanco et al., 2018), they are highly amorphous with a transition temperature of -62ºC to 25ºC, and a melting temperature of 42 to 58ºC. The elastomers are usually thermostable polymers, but they can also be thermoplastic, their elasticity comes from the ability of the chains to change their position by themselves and thus distribute an applied voltage (Valero-Valdivieso et al., 2013).

3 MIXED CULTURES

Faced with the problem of reducing production costs, interest in the investigation of mixed crops such as activated sludge that have been shown to be able to accumulate PHB under conditions of unstable state that are generated from an intermittent feeding regime increased. This is due to the fact that the biomass is subjected to successive periods of external substrate availability (fiesta period) and later it is without external substrate availability (hunger period). Under dynamic conditions, biomass growth and polymer storage occur simultaneously when there is an excess of external substrate. The latest studies have focused on the modeling and control of processes, the mechanisms of bacterial storage and the characterization of polymers.
The reserve accumulation rate is higher than the growth rate, due to the imbalance conditions, if the substrate is constantly supplied, the growth rate would be higher than the accumulation rate due to the physiological adaptation of the microorganisms (Montiel-jarillo et al., 2017).

There are two types of microorganisms that have been shown to be able to store PHAs in activated sludge reactors: 1. Organisms that accumulate polyphosphate (PAO) and 2. Organisms that accumulate glycogen (GAO). Those that are capable of accumulating polyphosphates are those that have shown the most capacity to produce storage polymers (PHA). PAOs and GAOs proliferate in systems in which the substrate is present regularly (Cech and Hartman, 1993). Different polymers are formed to allow the cells to balance the redox equivalents produced and needed in the conversion of the substrate to PHA (Satch et al., 1999).

The stoichiometric ratios of acetate uptake, glycogen consumption and PHA production are different for PAO and GAO. The YP / S coefficient of performance depends on the process and the substrate used. For PAO and GAO, the acetate-based YP / S as a carbon source is in the range of 1.21 - 1.43 and 1.58 - 1.93 respectively (Liu et al., 2011). Various analyzes have shown that a variation in pH can cause more PHAs are stored (Smolders et al., 1994).

According to Serafim, the use of mixed crops can help reduce operating costs by up to 50%, in the case of substrates at no cost can reduce this cost up to 85%. Rhu estimates that about 50% of the production cost of PHA is due to the cost of extracting the polymer.

The production of PHA in mixed cultures can be reduced if organic waste sources are used as a substrate, but the carbohydrate residues are not a good substrate for the production of PHA since they are transformed into glycogen. However, they can be converted if they are previously pre-fermented in volatile fatty acids (Moita Fidalgo et al., 2014).

The accumulation of PHA in mixed cultures can reach more than 60% of its dry cell weight, but it is still low compared to pure cultures which can reach more than 80% of its dry cell weight (Marang et al., 2014).

4 ACTIVATED SLUDGE MODEL

For the development of the work we will use the Activated Sludge Model 3 (ASM3), which was designed to be the core of different models, including energy reserve models, which is one of the characteristics necessary for the accumulation of polyhydroxyalkanoates (PHA) and Phosphorus biological removal modules. Next, the model to be used is further detailed (Gujer, n.d.), this model provides us with the backbone, which describes the processes of less interest in research, so that we can concentrate on new frontiers again. This model was designed to essentially meet the application needs of the model. The model ASM3 is based on the model ASM1 including some improvements among which are:

- Includes kinetic expressions.
- Excludes particulate and soluble organic nitrogen as components of the model because they are easy to quantify.
- The reason for the decay of nitrifiers can be identified in aerobic and anaerobic conditions.
- Among other.

In this model, the conversion processes of the organisms' present are carried out separately. The complexity of the ASM3 model can be compared with the ASM1. A correct characterization of the wastewater must be carried out in order to use the model. This model, like the ASM2, includes cellular internal storage components, which requires that the biomass be modeled with cellular internal structure. Decay processes must include both fractions of the biomass.

The ASM3 model uses the following components:

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S - \text{Soluble compounds} \\
X - \text{Particulate compounds}
\]

Particulate components are generally associated with activated sludge systems. These compounds accumulate in the sedimentation tanks in the case of the soluble compounds they are transported by water.

5 RESULTS

In general, the removal of pollutants from the wastewater has been converted into a well and the resulting parameters of the effluent are within the permitted ranges.

The production of polyhydroxyalkanoates is best given when there is an abundance of carbon substrate, when the substrate reduces the microorganisms to the stored polyhydroxyalkanoates for energy. It is possible that in aerobic conditions for long periods of air the accumulation of polyhydroxyalkanoates increased.
6 CONCLUSIONS

Polyhydroxyalkanoates can be produced in mixed cultures under different conditions, but having different conditions will vary the amount of polyhydroxyalkanoates accumulated. The best conditions for the accumulation of these are when there is excess carbonaceous substrate and there are long periods of aeration. The use of mixed cultures enriched under adequate conditions, might also be a promising option for polyhydroxyalkanoates production.

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REFERENCES


