Improvement of Anaerobic Digestion from Tapioca Starch Wastewater by Fungal Pretreatment

Watcharapol Wonglertarak* Boonchai Wichitsathiana[1]** Jareeya Yimrattanabavorna*** Borano Te****

(Received: *November 5, 2019;* Revised: *January 2, 2020;* Accepted: *January 7, 2020*)

ABSTRACT

In this paper, the improvement of anaerobic digestion from tapioca starch wastewater by fungal pretreatment at various HRT conditions was investigated. The tapioca starch from a factory was used for synthesis wastewater. The experimental set-up consisted of the Sequencing Batch Reactor (SBR) operated with 6-24 hrs of hydraulic retention time (HRT), and adjusted to the optimum pH of approximately 3.0±0.2. As the result, the optimal organic matter removal of 54% on this tapioca starch wastewater was found to be with the HRT of 24 hrs. In the biochemical methane potential (BMP) test, the HRT of 24 hrs also showed the highest COD removal efficiency of 60.6% amongst the pretreated systems. The fractional increase of the gas production in the anaerobic digestion with a fungal pretreatment was approximately 52.38% compared with the system without a fungal pretreatment.

Keywords: Tapioca starch wastewater, Fungal pretreatment, Biochemical methane potential (BMP).

[1]*Corresponding author: boonchai@sut.ac.th*

**Student, Doctor of Environmental Engineering Program in Institute of Engineering, Suranaree University of Technology, Thailand*

***Associate Professor, School of Environmental Engineering, Institute of Engineering, Suranaree University of Technology, Thailand*

****Assistant Professor, School of Environmental Engineering, Institute of Engineering, Suranaree University of Technology, Thailand*

*****Researcher, Faculty of Civil Engineering,Preah Kossomak Polytechnic Institute, Cambodia*

Introduction

In the tapioca processing factory wastewater discharges from root washing step and extraction step. The root washing wastewater contains a lower organic matter but higher inorganic content (sand). In all industries, after primary sedimentation the root washing wastewater is recycled. Extraction wastewater is high in organic content (COD) and suspended solid (SS). Main part of SS is organic matter (fiber). So wastewater from tapioca processing factory containing high COD, SS and low pH. The tapioca starch wastewater consists of some major organic components such as starch residue, free sugars, and the sugars formed by the amylolytic organisms that can be used as a substrate for a microbial biomass generation. Anaerobic process is a conventional wastewater treatment process used to stabilize organic matter, mass reduction, and methane production. However, the substrate needed to be pretreated by some methods for hydrolyzing starch to sugar. A septic operation condition and retention time longer than one day are required to carry out the processes. All these increase costs and uneconomical features for a commercial industrial application. It has been known that microbiological pretreatment could speed up the degradation rate of the substrates in an anaerobic digestion system. Bacterial and fungal cellulose-, hemicellulose- and starch-degrading enzymes are responsible for enhancing the substrate digestibility [1].

Conventional biological wastewater treatment normally generates a large amount of low-value bacterial biomass. The treatment and disposal of this excess bacterial biomass account for about 40–60% of the operational cost of a wastewater treatment plant. A different form of biomass with a higher value could significantly change the economic aspect of wastewater treatment. The biomass produced during fungal wastewater treatment has, potentially, a much higher value than that from the bacterial activated sludge process. And, fungal biomass is abundant in protein and can be used as additives for animal feeding. Different fungal strains have shown their ability to degrade a wide range of environmental pollutants [2]. A filamentous fungus, which has apparently been an essential part of an oriental food production for centuries, is known to have a wide range of enzymes, is capable of metabolizing complex mixtures of organic compounds occurring in most wastes, and has been determined to be suitable cultures for a treatment of a starch processing wastewater [3]. In the previous studied, biological pretreatment of waste with most widely studied filamentous fungi, such as *Geotrichum candidum*, *Coriolus versicolor*, *Phanerochaete chrysosporium*, and *Mycelia sterilia* showed around 55–73% of COD reduction within an incubation period of 10 days [4]. Reduction in soluble COD by 46% from corn stillage over 5 days using the mixed genera of *Aspergillus*, *Fusarium*, *Rhizopus*, Mucor, Rhizomucor, Absidia [5] and by 56% with *Aspergillus awamori* var. *kawachi* has also been accounted in the previous studies for the treatment of rice alcohol beverage wastewater [6]. Although, many technologies are developed to treat the wastewater, none of the processes showed convincing results to achieve safe and economically feasible disposal. Hence, there is an urgent need to address the limitations of the existing technologies and to develop a treatment process to provide a complete solution for the treatment of tapioca starch wastewater. In this paper, the evaluation of the performance and biodegradability on tapioca starch wastewater treatment by fungal at various hydraulic retention time (HRT) conditions was carried outs. Moreover, the effects of the pretreatment on the performance of anaerobic digestion and treatment efficiency were also investigated.

Objectives of the study

Evaluation of the performance and biodegradability on tapioca starch wastewater treatment by fungal at various hydraulic retention time (HRT) conditions.

Methodology

Synthesis of starch processing wastewater

The synthetic wastewater in this study was prepared by using the tapioca starch from a factory. Tapioca starch based synthetic wastewater was heated at 55±3°C to dissolve the particulate matters before feeding to the system. This was done to simulate a high strength particulate wastewater (tapioca starch wastewater) discharge at a high temperature. Tapioca starch was used as a sole carbon source. NH_4HCO_3 and KH_2PO_4 were added as nutrients. Characteristics and composition of the synthetic wastewater prepared according to Supawat [7] are shown in Table 1.

Synthesis of starch processing wastewater

The initial seed was isolated from the bottom sediment of an equalization tank from a tapioca starch factory. The enrichment process was carried out to cultivate naturally mixed fungi in the seed sludge [8]. The experimental set-up consisted of Sequencing Batch Reactors (SBR) operated with 6, 12, and 24 hrs of hydraulic retention time (HRT) [9] and the pH was adjusted to an approximately 3.0±0.2, which is the optimum pH for mixed fungi growth that can prevent bacterial contamination [10], which is the optimum value for the growth of the mixed fungi and possibly prevent bacterial contamination. Each cycle went through four main steps: filling, reacting (aeration), settling and drawing. The reactors were mixed and aerated by the compressed air through stone air diffusers to maintain a suitable mixing condition and to supply sufficient dissolved oxygen for microorganism growth (DO = 2 - 4 mg/L).

Biochemical methane potential assay

Biochemical methane potential (BMP) test was carried out to determine the biodegradability before and after fungal pretreatment under an ambient temperature condition in the batch anaerobic digester for around 20 days. Batch anaerobic digestion tests were conducted using bottles with a working volume of 500 ml. The sample from the systems with and without fungal pretreatments was mixed with inoculated sludge at the volume ratio of 70:30 and then put into conical flasks. Biogas production was measured by the water displacement method.

Sampling and Analytical Methods

The influent and effluent samples of the SBR were analyzed following the standard methods for the examination of water and wastewater [11]. SCOD was the measurement of COD in the soluble form. Biochemical oxygen demand (BOD) was determined with an OxiTop®-C measuring pressure head instrument (Expotech USA Inc., Houston, TX, USA). The carbonaceous material characterizations were measured in terms of the COD parameter subdivided into a number of fractions following [12].

Results

Effect of HRT on Fungal Pretreatment

The starch processing wastewater consisted of the quantified solid, organic and nitrogen contents. In accordance with Table 1, with a relatively high COD value (20800 mg/L), the soluble COD to COD ratio was approximately 11%. It shows that most part is a large and highly slowly degradable organic substance. This wastewater also contained a relatively low nitrogen content based on the COD:N ratio, which is likely too low for a conventional biological treatment process. The fungal SBR system produced the effluent with COD ranging from 8,500 to12,000 mg/L, corresponding to the removal efficiency of 36-54% for COD. The HRT of 24 hours showed an optimal condition for resulting in the highest removal organic matter of 54% on the studied tapioca starch wastewater when compared to the conditions with other HRT values (figure 1).

Takahiro et al. [13] investigated the treatability of wastewater containing either soluble starch or cornstarch using an internal-loop airlift reactor with Aspergillus niger in an open system. The result for wastewater containing 25g/l cornstarch showed that the removal efficiency of TOC and the degradation efficiency of starch reached 76% and 99%, respectively. Truong et al. [14] used Aspergillus oryzae for the treatment of the cassava starch processing wastewater, and observed both pellets and freely dispersed hyphal elements at pH 3.0. The treatment efficiencies obtained for TOC, COD and starch after 96 hrs were 72%, 75% and 77%, respectively.

COD fraction on fungal pretreatment

The COD fractionation was evaluated for representing the biodegradability potential. The influent contained a slowly biodegradable fraction (X_s) and readily biodegradable fraction (S_s) of about 65.34% and 5.29% of TCOD, respectively. The tapioca starch wastewater has a high molecular weight that is hardly biodegradable by heterotroph bacteria. After treating with fungal, readily biodegradable fraction (S_s) increased to about 8.97% of TCOD at HRT of 24 hours. This, indicates that the biodegradable fraction can be increased through the fungal utilization. Furthermore, the effluent had the BOD/COD ratio of 0.66 at HRT of 24 hours, as shown in figure 2. This suggested that 24 hours was the optimal value of HRT for applying the fungal pretreatment on the studied anaerobic digestion.

Effect of Fungal Pretreatment on Biochemical methane potential

Biochemical methane potential (BMP) test was carried out to determine the biodegradability before and after the pretreatment under an ambient temperature condition in the batch anaerobic digesters for around 20 days. Organic compound reduction before and after timplementing of the pretreatment is presented in figure 3. It shows that the highest COD removal efficiency of 60.6% in the fungal pretreated system was found with the application of 24 hours of HRT. The gas productions at the end of the studied period were 189, 183, 229, and 288 L/kg COD for the non-fungal pretreatment and the pretreatment with 6, 12, 24 hrs of HRT, respectively. Apparently, the fungal pretreatment condition results in an improvement of the gas production because the applied process help to hydrolyze much organic matter containing in the substrate into readily biodegradable forms that allow the anaerobic digestion to immediately consume.

Discussion and Conclusions

The tapioca starch wastewater with slowly degradable compounds was a disadvantage of an anaerobic digestion or a conventional digester. Fungal pretreatment is capable of improving biodegradability by increasing readily biodegradable fraction (S_s). And, the HRT of 24 hours was the optimal value for fungal pretreatment on anaerobic digestion in this study. In biochemical methane potential test, the higher removal efficiency for COD of 60.6% was obtained for the HRT of 24 hrs compared to the pretreated systems with other HRTs. The gas production was significantly improved after fungal pretreatment was applied under the studied conditions. Quantitatively, the increase of gas production was approximately 52.38% compared to the non-pretreated system.

Acknowledgements

This work was supported by Thailand Institute of Scientific and Technological Research and Suranaree University of Technology and Thailand Institute of Scientific. We would like to thank the staff for their continual assistance in preparing and carrying out this research in the Institute of Environmental Engineering, Suranaree University of Technology.

References

1. Sameh S, Ali1 Jianzhong S. Physico-chemical pretreatment and fungal biotreatment for park wastes and cattle dung for biogas production. SpringerPlus. 2015; 4: 1-14.
2. Maza-Marquez P, Vilchez-Vargas R, Kerckhof FM, Aranda E, Gonzalez-Lopez J, Rodelas B. Community structure, population dynamics and diversity of fungi in a full-scale membrane bioreactor (MBR) for urban wastewater treatment. Water Research. 2016; 105: 507-519.
3. Jin B, Van Leeuwen HJ, Patel B, Yu Q. Utilization of starch processing wastewater for production of microbial biomass protein and fungal -amylase by Aspergillus oryzae. Bioresour. Technol. 1999; 66: 201–206.
4. González T, Terron MC, Yagüe S, Zapico E, Galletti GC, González AE. Pyrolysis/gas chromatography/mass spectrometry monitoring of fungal biotreated distillery wastewater using Trametes sp. I-62 (CECT 20197). Rapid Commun. Mass Spectrom. 2000; 15: 1417–1424.
5. Van Leeuwen J, Khanal SK, Pometto AL, Rasmussen ML, Mitra D. Fungi cultivation on alcohol fermentation stillage for useful products and energy savings. Civil, Construction and Environmental Engineering Patents. 2013.
6. Kida K, Morimura S, Abe N, Sonoda Y. Biological treatment of Shochu distillery wastewater. Process Biochem. 1995; 30 (2): 125–132.
7. Supawat C. Effect of PVA-Gel on Performance Improvement of a Two Stage Thermophilic Anaerobic Membrane Bioreactor [Ph.D. thesis]. Asian Institute of Technology; 2015. Thai.
8. Patcharin R. Investigation of downflow hanging sponge (DHS) system using bacterial and fungal cultures as a post treatment for the UASB effluent of a tapioca starch wastewater [Ph.D. thesis]. Suranaree University of Technology; 2009. Thai.

9. Lei Z, Guang-Li C, Ai-Jie, W, Hong-Yu R, Nan-Qi R. An anaerobic sequential batch reactor for enhanced continuous hydrogen production from fungal pretreated cornstalk hydrolysate. International journal of hydrogen energy. 2014; 39: 19311-19316.

10. Takahiro S, Naoyuki M, Keisuke I. Treatment of High-Strength Wastewater Containing Cornstarch by Internal-Loopm Airlift Reactor with Aspergillus niger Pell. Japanese Journal of Water Treatment Biology. 2001; 37 (3): 111-116.

11. APHA, AWWA, WEF. Standard methods for the examination of the water and wastewater. Washington D.C.: American Public Health Association. 2005.

12. Wentzel MC, Mbewe A, Lakay MT, Ekama GA. Batch test for characterization of the carbonaceous materials in municipal wastewaters. Water SA. 1999; 25(3): 327-336.

13. Takahiro S, Naoyuki M, Keisuke I. Treatment of High-Strength Wastewater Containing Cornstarch by Internal-Loopm Airlift Reactor with Aspergillus niger Pell. Japanese Journal of Water Treatment Biology. 2001; 37 (3): 111-116.

14. Truong QT, Naoyuki M, Keisuke I. Growth of Aspergillus oryzae during Treatment of Cassava Starch Processing Wastewater with High Content of Suspended Solids. Journal of bioscience and bioengineering. 2004; 97(5): 329–335.

Table 1 Composition and characteristics of starch processing wastewater

Parameter	Unit	Concentration
pH	-	7.5
COD	g/l	20.8
SCOD	g/l	2.32
BOD	g/l	14.69
SBOD	g/l	1.10
TS	g/l	15.6
TSS	g/l	13.6
TKN	mg/l	950
$N\text{-}NH_3$	mg/l	680

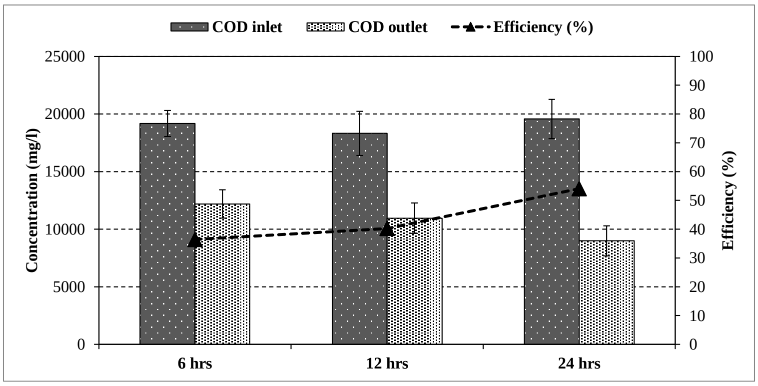

Figure 1 Efficiency organic removal of fungal treatment at various HRT

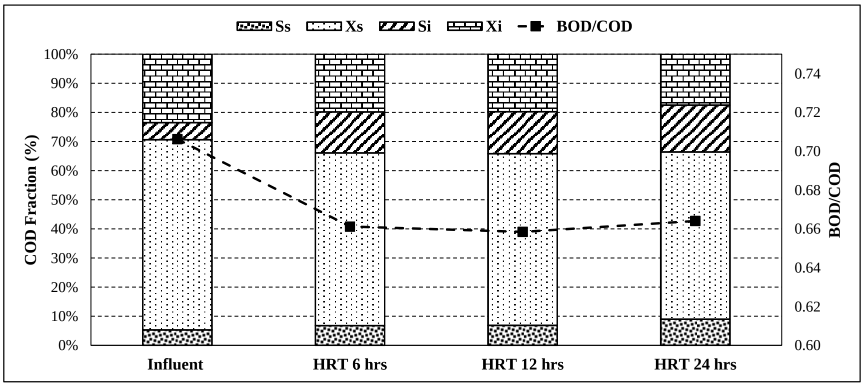

Figure 2 The COD fractionation and biodegradability of fungal treatment at various HRT

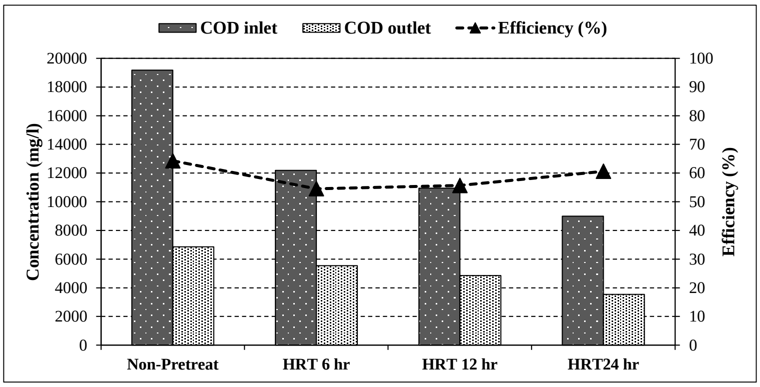

Figure 3 Efficiency organic removal of fungal pretreatment on BMP test

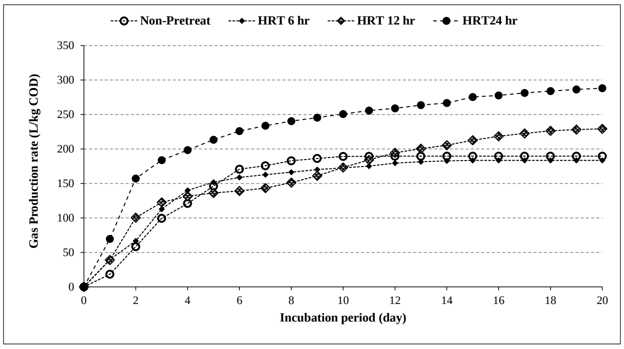

Figure 4 Cumulative gas productivity of fungal pretreatment