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Study of Starch and Sugar Degradation and Transformation during Biotreatment Process of Wastewater from Rice Vermicelli Production at Craft Villages in Vietnam

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Abstract

All steps in the rice vermicelli production discharged a big volume of wastewater containing significant amount of starch and sugar, except rice soaking. During the microbiological treatment, its known that starch, sugar or other carbon hydrates were disintegrated and transformed into finally simple molecular such as methane, carbon dioxide and water. But how is it happened is a question need to be further investigated. The result of this work partly showed outthat, in the aerobic biotreatment process, starch and sugar concentration was continuously decreased in unchanged pH value during the treatment process. This counted that there was the biodegradation overwhelmed. The concentration of starch and sugar in biomass was sharply increased at the beginning hours was determined as a result of adsorption of organic matter on the biomass.However, in the anaerobic process, the variation of starch and sugar concentration was more complicated. The increase of sugar concentration in acidic phase was considered as a result of the chemical hydrolysis beside biodegradation of the starch. In this very work, in the different stages of treatment processes, the disintegration rates of starch and sugar were determined and their distribution in the solution and in the biomass during the treatment processes was discussed.

Keywords: Craft villages; rice vermicelli production; wastewater biotreatment; starch and sugar transformation

1. Introduction

Wastewater containing high concentration of easy disintegrative compounds is very sensitive upon environment due to its high rate disintegration to produce high pollution intensity for water, air and soil environments. One of these categories is wastewater of agricultural products processing in Vietnamese craft villages, such as production of soy bean curd, rice vermicelli and starch. COD in such wastewater reached to several ten thousand mg/L and the ratio of BOD per COD is up to 0.9 due to high concentration of starch and protein. During the rice vermicelli production, wastewater from rice washing and vermicelli boiling contain amount of starch up to 4.36 and 8.67 g/L respectively (Tran *et al*., 2010). The treatment of wastewater with high starch concentration was studied and proposed various realizable technologies (Tran *et al*., 2006; Rajansimman and Karthikey, 2007; Weiguo *et al*., 2010; Annachhatre and Amornkaew, 2001; Frostel, 1983). The studies were also interested in starch recovery and reuse of products recovered from treatment processes (Tran *et al*., 2006; Ohnishi, 2002; Del Re *et al*., 2003). Because of the low cost price of agricultural products and the request of essential food valorization, the investment for wastewater treatment of agricultural processing area was limited.In order to reduce production cost, the use of every possible recoverable thing is indispensable to the field of agricultural processing and production. Investigation of starch and sugar transformation and disintegration during wastewater treatment in this work was aimed to develop understanding and evaluation of valuable products recoverable from the treatment. In complicated nutrient transformation of microorganisms in the wastewater containing starch treatment, the step of starch sorption and transformation into glucoside is plays important role for effective recovery of high nutrient value biomass and separation subdivision enzyme glucoasa (Ohnishi, 2002; Del Re *et al*., 2003). In this work the wastewater containing high starch concentration from rice vermicelli production was used as asubject in the biodegradation study. The variation of COD value, starch and sugar concentration was surveyed and analyzed. In the report the hypothesis of starch and sugar transformation and transformation rate during treatment process were discussed.

2. Materials and Methods

2.1. Samples for Experiment

The study samples were collected from boiling step of rice vermicelli production in craft household in Phu Do village, Hanoi city. After collection, the pH, COD

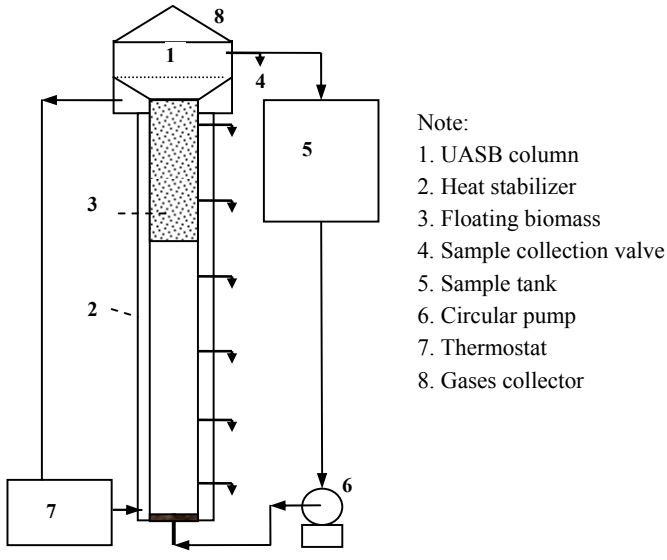

Figure 1. Anaerobic treatment system

value, starch and sugar concentration in the samples were immediately analyzed; then brought into aerobic or anaerobic biotreatment system for main investigation.

2.2. The Bioreactors

For anaerobic treatment, the UASB system with batch reactor was used. The reactor is column shape with effective volume of 6.5 liters and about 2 liters of floating biomass.The main reactor was connected with a wastewater sample containing tank of 7.0 liters effective volume, circulation pump, sample collection valve in the top of the column and was heat stabilized by water thermostat system (Fig. 1). The biomass sticking on the floating support was primarily grown and stabilized for 15 days. Before putting sample into the reactor, thewater phase, which used for microbial growing was drained off then sample was pumped into the reactor and start investigation.

The aerobic reactor (Fig. 2) is plastic tank of 10 liters volume connected with settling tank. The regulable air compressor was equipped for oxygen supply and keeping DO in the wastewater phase always in the value around 4.0 mg/L. The biomass density was controlled to be always around 10% V/V in the aerobic tank by the sludge draining valve.

During the treatment process, samples were collected periodically along treatment time. The concerning parameters were analyzed by standard and suitable methods (APHA, 1995).

2.3. Analysis of Parameters in Water Phase

The suspension samples were taken from biodegradation tank with volume about 100 ml each. The sample was then filtered through the porous filter 0.45 µm. The filtrate was taken for determination of COD value, starch and sugar concentration. The solid part used for determination of starch and sugar in biomass.

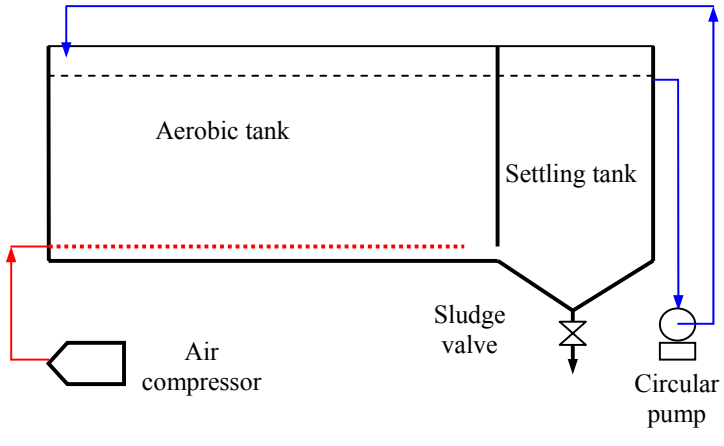

Figure 2. Aerobic treatment system

COD value was analyzed by dichromate method and photometric measure at wavelength of 605 nm.Starch and total sugar amount were analyzed by Bertrand method (Bertrand and Thomas, 1910). This method is based on determination of total sugar initially in the sample and sugar amount after starch hydrolysis completely in the same sample. The starch concentration is deference of analytical results of two above analyses multiplied by 0.9.

2.4. Analysis of Starch and Sugar in Biomass

The solid part on the filter mentioned in section 2.3. was washed several times by deionized water, and then was dried at 60°C in vacuum until reached constant weight. The dried biomass wasthen soaking in approximately 30 ml deionized water and stirring to be crumbled. Sample was disintegrated by ultrasound for 30 min, filtered and washed by deionized water. Filtrate and washed water were mixed and filled to 50 ml. Starch and sugar in this solution was determined by the method mentioned in section 2.3.

3. Results and Discussion

3.1. Transformation of Starch and Sugar in Anaerobic DegradationSystem

Anaerobic batch degradation in UASB system was carried out for 120 h. Initial sample had average COD value of 8425 mg/L, starch concentration of 5437 mg/L and sugar concentration of 1460 mg/L. The variation of COD value and starch and sugar concentration was described in Fig. 3.

The graphs of surveying parameters variation in Fig. 3 showed that during first 8 hours of anaerobic treatment, the COD value sharply decreased. The reason of the sharpdecrease of COD value was not only result of microbial digestion but mainly was sorption of organic matter on biomasssurface. After that COD value was decreased not shape as before and was almost linear with minus slope coefficient corresponding to decrease of-47.34. The degradation rate of COD can calculate by common equation: $w = -\frac{\partial[COD]}{\partial t} = -\frac{\Delta[COD]}{\Delta t}$ because of degradation of COD vs the time from 8th hour to 120th hour was reckoned as a linear graph. Replace theΔ[COD] and Δt in the equation with real measured values to recover average degradation rate, which is –45.9 mg/L.h. The average specific digestion rate of biomass in the treatment system was 25 mg/dm^3.h. After 120 hours treatment, the COD value remained at about 2000 mg/L.

In the case of starch, the shape decrease of its concentration in first 8 hours mainly was also the result of biomass sorption in order to establish concentration equilibrium between water phase and biomass phase. After that, starch concentration still quickly decreased in next 48 hours from 3612 mg/L to 721 mg/L. The average degradation rate, w in this period was –72 mg/L.h (the calculation was similar calculation of COD degradation rate) and after 120 h treatment, starch concentration still remained 186 mg/L. That means starch digestion in anaerobic conditions was slow and difficult to complete. The most rapid digestion was happened in the period, where acidic phase predominated in UASB system with pH level decreased from 6.4 to 5.4 then increased to 6.3 (corresponding from 8th hour to 56th hour).

The variation of sugar concentration in water phase was different than that of COD and starch. That is when pH decreased and treating wastewater was

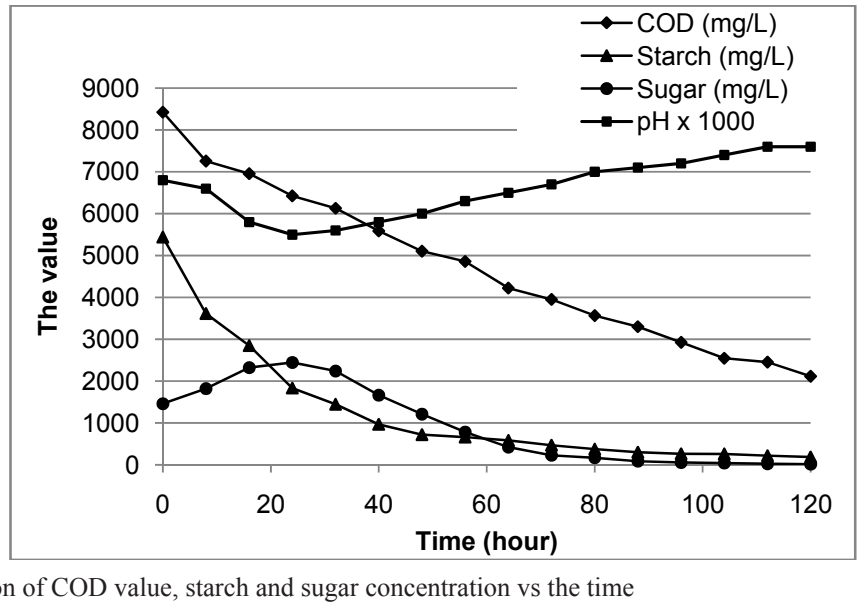

Figure 3. The variation of COD value, starch and sugar concentration vs the time

being in acidic phase, the sugar concentration increased. The reason of this phenomenon could be the chemical hydrolysis rate of starch in acidic condition was higher than sugar sorption of biomass in this period. In the next period from 32th hour to 64th hour, there was fastest decrease of sugar concentration and it was almost linear vs. the treating time. The average degradation rate, w of sugar concentration reached –57.5 mg/L.h. In this period, the starch concentration was not high as before, the pH value increased and was high enough, the chemical hydrolysis of starch was terminated and simultaneously the biomass density was higher than initial one. Then sugar concentration decreased gradually and until 120 h remained 16 mg/L only.

In the anaerobic investigation, the content of starch and sugar in biomass was not determined because floating solid phase containing biomass stickling on porous plastic support was fixed and unable to take out.

3.2. Transformation of Starch and Sugar in Aerobic Disintegration System

The aerobic investigation was carried out in aerobic batch reactor with wastewater circulation as describes in section 2.2. The result of COD value, starch and sugar concentration variation in water phase was showed in Fig. 4.

Before filling of wastewater into aerobic system,the biomass in aerobic tank was left to settle for 45 min, and feeding solution was drained out. The biomass sludge (about 10% effective volume of aerobic tank) was retained. Experiment started when wastewater filled into the aerobic tank. In the first hour, COD value and both starch and sugar concentration sharply decreased. This case could be the same reason of organic sorption on biomass and establishment of concentration equilibrium between water and microbial phases.From second hour, the COD value decreased gradually and almost linearlywith average degradation rate of –533.7 mg/L.h. After 10 h, COD value remained 1864 mg/L only (the initial value was 8367 mg/L). That means in comparison with anaerobic treatment, COD degradation rate in aerobic treatment was approximately more than 10 times higher, while initial value was almost the same.

In regard to starch and sugar in aerobic treatment, the concentration of both reduced quickly. After 5 hours from beginning, sugar concentration in wastewater reached almost zero and after 10 hours, starch was almost disintegrated completely. There was unrecognizable hydrolysis of starch to identify by increasing of glucose concentration in water phase. In this case, transformation of starch occurred mainly in the cells of microorganisms. In case the hydrolysis of starch happened in the water phase, its rate was always lower than glucose sorption rate of microorganisms in the biomass.Moreover, the pH value during aerobic treatment in the investigation was almost stable around 6.8. In that condition, the chemical hydrolysis of starch was impossible.

3.3. Determination of Starch and Sugar Content in Aerobic Biomass

The biomass sample was treated as mentioned in section 2.4., starch and sugar content was determined by the methods mentioned in section 2.2. The result, that was analyzed through 20 hours along the treating time was shown in Fig. 5.

As graphs in Fig. 5, in first 2 hours, the content of starch and sugar sharply increased. This result is almost suitable with hypothesis mentioned in sections before that starch and sugar were accumulated on biomass in first hours when biomass contacts with wastewater containing high concentration of starch and sugar. Then content of both quickly decreased in next 8 to 10 hours with the rate of -31.4 mg/L.h. The concentration of starch then decreased continuously to almost zero

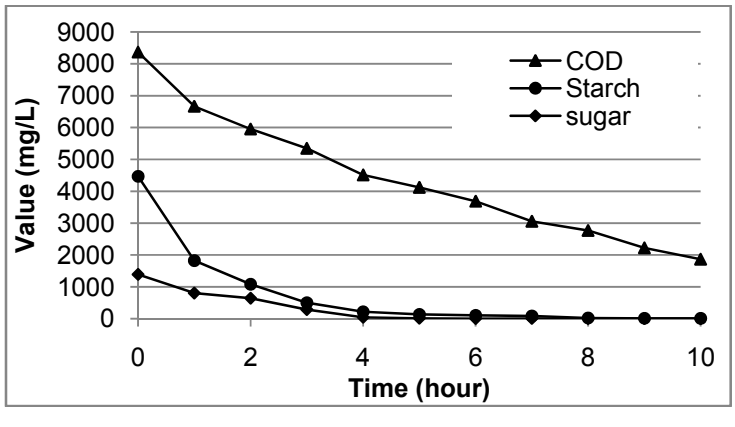

Figure 4. Variation of COD value, starch and sugar concentration

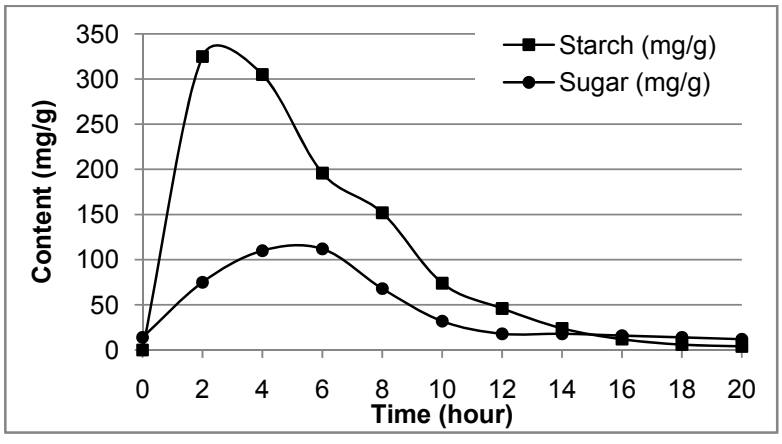

Figure 4. Variation of COD value, starch and sugar concentration

in 20th treating hour. The initial content of sugar in biomass was determined 14 mg/g. The reason of present of sugar in initial biomass is that, biomass growing process used glucose as nutrient and final COD value in growing solution before draining was determined about 100 mg/L. There was different to starch, the sugar content increased until 5th hour. By our opinion, when content of starch in biomass is still high enough, the disintegration rate of starch in microorganisms is also increased and sugar was accumulated in their cell. So the increase of sugar was lengthened than that of starch. Then the sugar content quickly decreased in continued 4 or 5 hour and then slowly until 20th; where its content still remained about 10 mg/g.

4. Conclusion

Investigation of starch and sugar disintegration in rice vermicelli wastewater (the wastewater containing mostly starch) by microbial treatment methods showed that disintegration rate of starch in aerobic treatment was almost 10 times higher than that in anaerobic treatment with UASB system. However in both treatment processes, the COD value, starch and sugar concentration were sharply decreased in first treating hours. The reason was considered as sorption of organic matter on the biomass in first contact time in order to establish concentration equilibrium.

In disintegration by UASB technology appeared phenomenon that sugar concentration in wastewater increased in the first treating hours where pH decreased and acid phase was temporarily predominating. Thesuggestion is that, this phenomenon was result of the starch hydrolysis outside biomass and its rate was higher than sugar sorption on the biomass. In the disintegration in aerobic condition, the concentration of starch and sugar in wastewater quickly decreased. After 10 hours only, starch and sugar were almost completely disintegrated.

The content of starch and sugar in biomass sharply increased in first 2 hours due to sorption of organic matter in wastewater onto biomass. The content of starch then decreased to almost zero after 20 treating hours, while the content of sugar decreased to minimum value of 10 – 14 mg/g. This value was considered as glucose accumulation in microorganism's cell according to the time and conditions of the investigation.

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