Utilization of Rice Bran to Prevent Bulking in the Activated Sludge Process

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Rice bran was evaluated for the prevention of bulking in the activated sludge process. After the addition of rice bran to the aeration tank of a food plant, a decrease in the sludge volume index was observed. Both biochemical oxygen demand and chemical oxygen demand showed significant decreases relative to that before the addition of rice bran. Rice bran accelerated the growth of the effective microorganism and thus inhibited the growth of filamentous organisms that cause bulking. The results suggest that phytic acid in rice bran is useful in controlling filamentous bulking in laboratory-scale investigations.

Key words —— rice bran, biochemical oxygen demand, chemical oxygen demand, sludge volume index, phytic acid

INTRODUCTION

The activated sludge process of wastewater purification is one of the most common processes for organics, which causes increased biochemical oxygen demand (BOD). In a properly operating activated sludge system, most of the bacteria, protozoa, and other organisms are gathered in flocculent masses in the activated sludge itself. Bacteria, not fungi, are primarily responsible for the degradation of waste in the activated sludge process. The mechanism of removal of organic material by bacteria can be generalized in the oxidation of organics and is generally called respiration and synthesis. The performance of the activated sludge process is limited by the ability of the secondary sedimentation basin to separate and concentrate the activated sludge from the treated effluent. During normal operations, mixed liquor flows from the aeration tanks into the final settling tanks. The activated sludge forms flocs, settles, and the effluent flows over the weirs of the final tank. The development of a low-density floc with poor settling characteristics and causing a poorly clarifed effluent is known as bulking. This phenomenon is a major problem in the activated sludge process. It was observed by many workers that filamentous bacteria were often present in large numbers when bulking occurred.[1)] Filamentous bulking is the most frequently reported cause of poorly settling sludge in activated sludge treatment plants.[2,3)] Farquhar and Boyle[4)] reported a correlation between the number of measurable filaments in a floc and high sludge volume index (SVI) values. Bulking has been associated with such characteristics of raw waste as septicity, heavy organic load, trade waste, mineral oil, and carbonaceous content.[5)] Inhoff and Fair[6)] reported that treatment used to reduce the SVI of bulking sludge includes reduction of the amount of return sludge and wasting more sludge in an attempt to build up a new microbiologic population, addition of flocculating chemicals to help settling of the sludge, and chlorination of the return sludge to destroy the filamentous organisms. Chlorine[7,8)] and hydrogen peroxide,[9,10)] the most common treatment for the elimination of filamentous organisms, have the disadvantage that they also can destroy desirable spherical bacteria.[11,12)] More recently, Madoni *et al*.[13)] have reported the results of a survey in Italy showing that the use of chlorination was successful in only 63% of cases. The addition of synthetic polymer is one common way to solve the poor sludge-settling problem immediately.[14)] One problem with this method is cost. A new method is needed to eliminate filamentous growth without extensive damage

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to the normal spherical aerobic population. We therefore studied several substances to find an effective one to eliminate filamentous organisms. In the process of these examinations, it was found that rice bran prevented bulking in the activated sludge process. This paper describes the use of rice bran in food plant and laboratory activated sludge systems.

MATERIALS AND METHODS

Materials ——— Rice bran was purchased at a local market. The composition of the rice bran is shown in Table 1. All chemicals used were of reagent grade.

Experimental Methods in Plant Tests ——— The water treatment method used in this plant is an activated sludge process. The activated sludge plant consisted of an aeration tank (54 m^3) and sedimentation tank (27 m^3). Raw water enters the aeration tank from the food plant which produces etiolated seedlings. The wastewater then flows from the aeration tank to the sedimentation tank. Most of the fine flocs or particles settle in the sedimentation tank. Finally, treated wastewater is drained through an outlet. The plant currently treats about 90 m^3 of raw water per day. The quality of the raw water is shown in Table 2. The addition of the rice bran (2 kg) to the aeration tank of the food plant started once per week from December 7 and continued once per month from February.

Analyses ——— The influent and effluent pH, suspended solid (SS), chemical oxygen demand (COD), BOD, total nitrogen, and total phosphorus were determined according to the method described in the Official Gazette.[15] The SV_{30} value is determined by settling a 1000-ml sample of mixed liquor for 30 min in a 1000-ml graduated cylinder. The SV_{30} can be expressed as: SV_{30} = volume of sludge settled in 30 min/sample volume. The SVI is the volume in milliliters occupied by 1 g of sludge after 30 min of settling, and the volume occupied by the sludge is reported as a percentage. SVI can be expressed as: SVI = % volume of sludge settled in 30 min/% suspended solids. Mixed liquor suspended solids (MLSS) are the concentration of suspended solids in a 1000-ml sample of mixed liquor.

Experimental Apparatus for Laboratory Tests ——— The experimental apparatus for the activated sludge process was a Miyamoto Model AS-5 and consisted of an aeration tank (5 l) and a sedimentation tank (2.4 l), which was used on a laboratory scale. The return sludge rate, MLSS, and dissolved oxygen (DO) are controlled by a control system linked with this system. Our experiments were carried out using each of these systems.

Table 1. Composition of Rice Bran

Constituent	Concentration (g/100 g)
Water	13.5
Protein	13.2
Lipid	18.3
Carbohyrdate	
Glucide	38.3
Fiber	7.8
Ash	8.9

Table 2. Water Quality of Raw Water from the Food Plant

Parameter	Range
pH	6.6–7.4
SS (mg/l)	12–92
COD (mg/l)	16–160
BOD (mg/l)	14–292
Total nitrogen (mg/l)	1.5–8.7
Total phosphorus (mg/l)	0.3–3.3

Preparation of Bulking for Laboratory Tests ——— Bulking was established and synthetic sewage was prepared following the method of Kuboyama.[16] The synthetic sewage was added to the aeration tank at 0.5 l/day for the first 5 days, at 0.65 l/day for an additional 6 days, and at 2.2 l/day for the subsequent 11 days. Bulking conditions were judged based on the presence of numerous filamentous organisms detected in microscopic examination of the sludge and a SVI value of 200 or higher.

Statistical Analysis ——— Values are expressed as mean ± S.D. Data were analyzed using one-way analysis of variance (ANOVA) and, when appropriate, the Student-Newman-Keul test. Results were considered significant at a p-value < 0.05.

RESULTS AND DISCUSSION

Figure 1 shows the variation in SV_{30}, SVI and MLSS in the aeration tank of the food plant. After the addition of rice bran, the SV_{30} value began to decrease gradually. The SVI steadily improved from 150 to approximately 70. The SVI is one measure employed to determine the settling qualities of sludge and is useful as a relative indicator of bulking conditions. Good sludge has an index of 50 to 100,

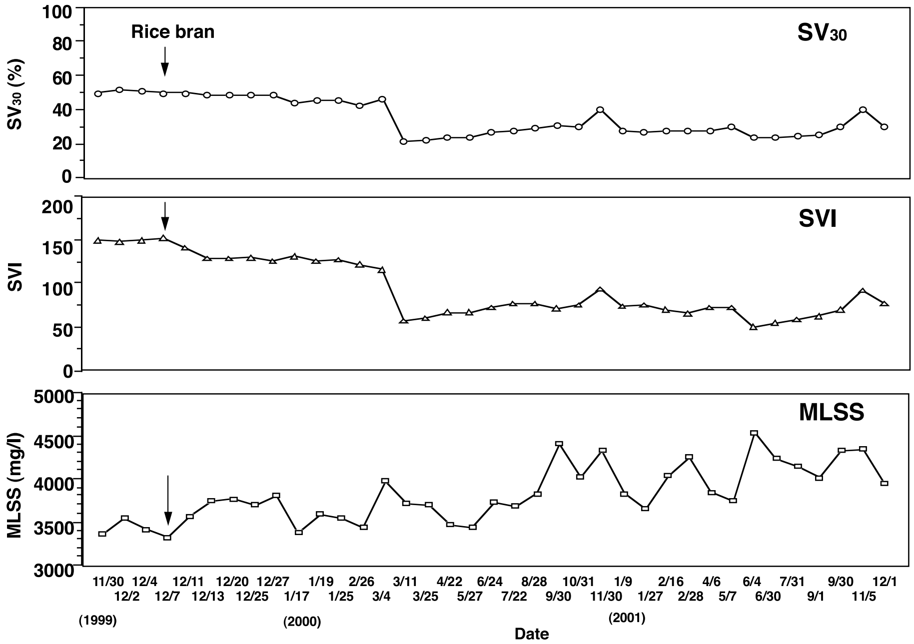

Fig. 1. Variations in SV_{30}, SVI, and MLSS in the Aeration Tank of a Food Plant
The addition of rice bran (2 kg) to the aeration tank of the food plant started once per week from December 7 and continued once per month from February.

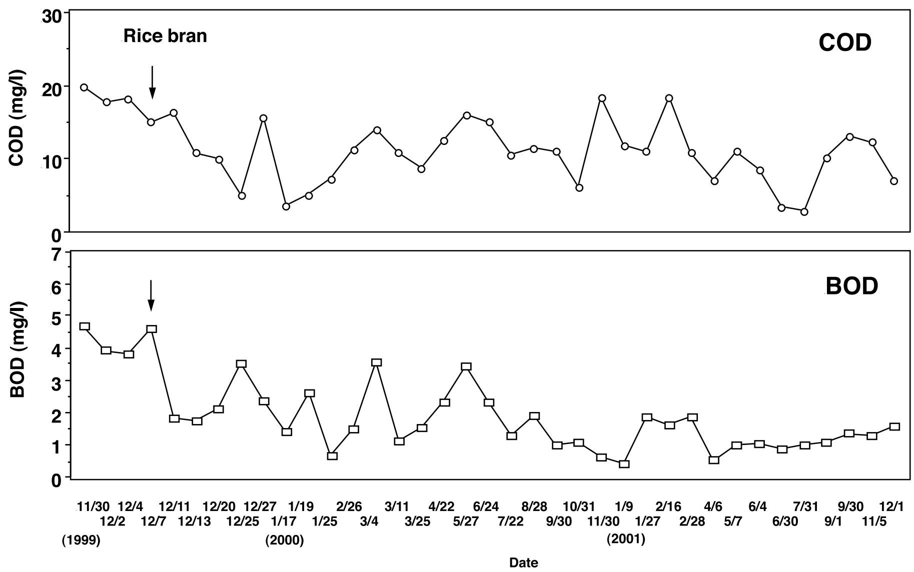

Fig. 2. Variations in COD and BOD in Activated Sludge Plant Effluents
The addition of rice bran (2 kg) to the aeration tank of the food plant started once per week from December 7 and continued once per month from February.

whereas poor sludge, with bulking characteristics, may have an index of 200 or higher. After the addition of rice bran, the MLSS value began to rise gradually from 3300 to 4000 mg/l. These results show that rice bran accelerates the growth of effective bacteria to produce sludge with good settling qualities. A comparison of treated water quality before and after the addition of rice bran is shown in Fig. 2. Both COD and BOD reductions were obtained after the addition of rice bran was begun. Both COD and BOD are means of assessing the degree of pollution of waste and are employed as measures of the amount

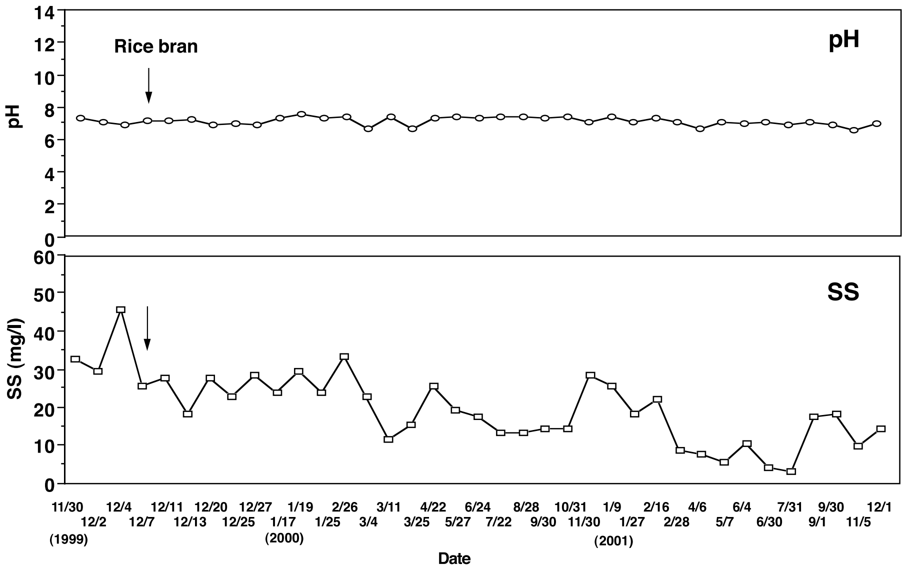

Fig. 3. Variations in pH and SS in Activated Sludge Plant Effluents

The addition of rice bran (2 kg) in the aeration tank of the food plant started once per week from December 7 and continued once per month from February.

Table 3. Assayed Values of pH, SS, Total Nitorogen, Total Phosphorus,COD, and BOD in Activated Sludge Plant Effluents

Sample	n	pH		SS (mg/l)		Total nitrogen (mg/l)	
		Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.
Without rice bran	16	7.0–7.4	7.2 ± 0.1	10–62	25 ± 14.5	2.2–4.4	3.3 ± 0.7
With rice bran	33	6.7–7.5	7.2 ± 0.3	6–35	21 ± 7.9	0.7–5.9	2.7 ± 1.1
Sample	n	Total phosphorus (mg/l)		COD (mg/l)		BOD (mg/l)	
		Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.
Without rice bran	16	0.2–0.8	0.6 ± 0.2	13.7–23.7	16.7 ± 2.8	2.2–6.7	3.8 ± 1.3
With rice bran	33	0.5–1.3	0.7 ± 0.2	5.9–18.7	12.3 ± 3.4[a]	0.6–3.6	1.7 ± 0.9[a]

a) Significantly different from the same date without rice bran, $p < 0.01$.

of organic material in samples. As shown in Table 3, both COD and BOD decreased significantly from 16.7 to 12.3 mg/l, and from 3.8 to 1.7 mg/l, respectively. Rice bran accelerated the growth of effective microorganisms. Both pH and SS in the effluents after treatment showed significantly less variation during the experimental period (Fig. 3). Rice bran does not affect pH and SS values. If an increase in SS were observed, the rice bran in the final tanks would spill over the weirs and the BOD of the final effluent would increase. These results showed that rice bran did not overflow in the treated water. In raw wastewater, the total nitrogen concentration was 1.5–8.7 mg/l and total phosphorus 0.3–3.3 mg/l (Table 2). In treated water, the total nitrogen and total phosphorus concentration before and after the addition of rice bran were from 3.3 to 2.7 mg/l and from 0.6 to 0.7 mg/l, respectively (Table 3). Rice bran contains adequate nitrogen and phosphate. In our laboratory tests, it was confirmed that nitrogen and phosphate did not dissolve from rice bran. Rice bran accelerated the growth of the effective microorganisms and suppressed the growth of filamentous bacteria that cause bulking. The effects of rice bran on the growth of the effective microorganisms was further examined on the laboratory scale using our experimental apparatus.

One gram of rice bran was added five times every second day to the aeration tank, after bulking had been confirmed by microscopic examination and the SVI value. Figure 4 shows the variation in SVI and MLSS in the aeration process before and after rice bran addition. SVI improved from between 300 and 400 to approximately 90 for several days immediately after rice bran addition. Figure 5 shows the variation in COD and BOD in the effluents after

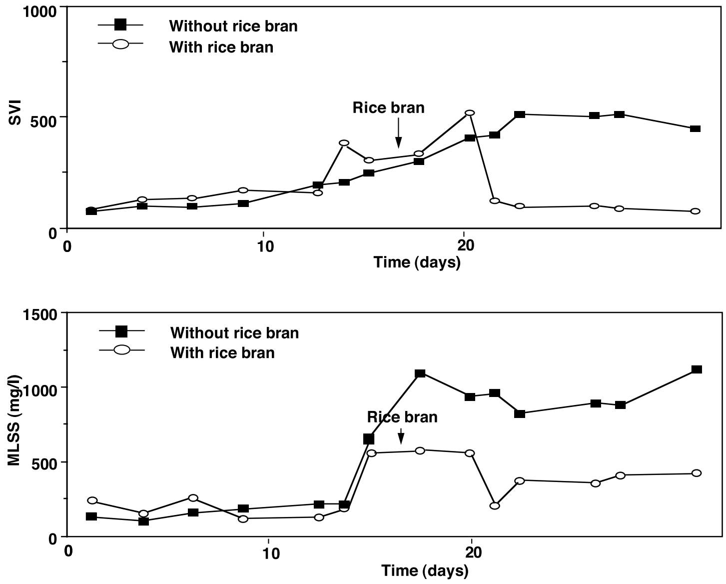

Fig. 4. Variations in SVI and MLSS in the Aeration Tank before and after Rice Bran Addition

One gram of rice bran was added five times every second day to the aeration tank after bulking had been confirmed by microscopic examination and SVI value.

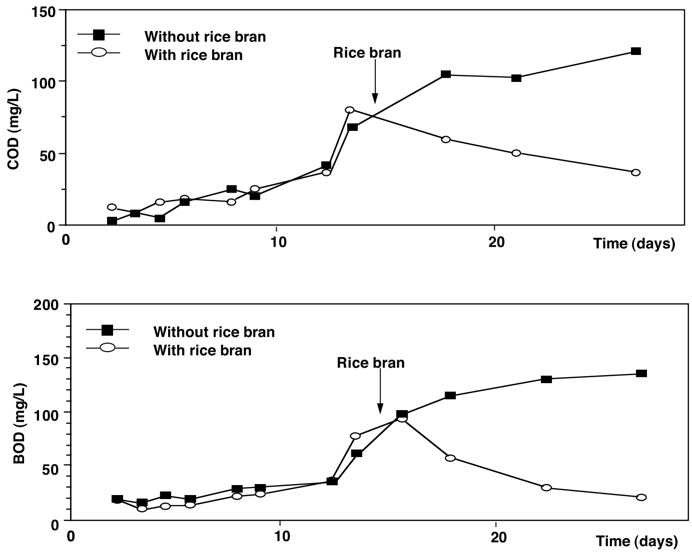

Fig. 5. Variations in COD and BOD in Effluents after Treatment before and after Rice Bran Addition

One gram of rice bran was added five times every second day to the aeration tank after bulking had been confirmed by microscopic examination and SVI value.

treatment. The addition of rice bran improved the COD to 50 mg/l and BOD to between 20 and 50 mg/l. As shown in Fig. 6, long, filamentous organisms were reduced immediately with in 3 days after rice bran addition.

Next, we investigated the mechanism of the effects of rice bran. Green *et al.*[17] reported that phytic acid is abundant in rice grains and is a potent chelator of essential minerals and proteins. Nishikawa and Kuriyama[18] found considerable amounts of phytic acid in activated sludge. They[18] reported that phytic acid and metal ions make a notable contribution to the properities of the activated sludge examined. We attempted to determine the amount of phytic acid in rice bran using the colorimetric method[19] and found that contained 3–4% phytic acid. It is therefore considered that the inhibition of bulking by rice bran is due to phytic acid. Next, the effects of phytic acid

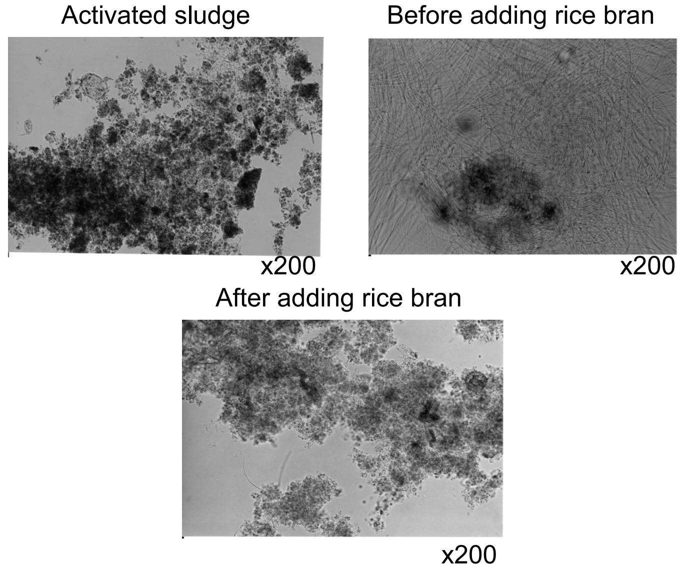

Fig. 6. Light Micrograph of Activated Sludge in the Aeration Tank before and after Rice Bran Addition

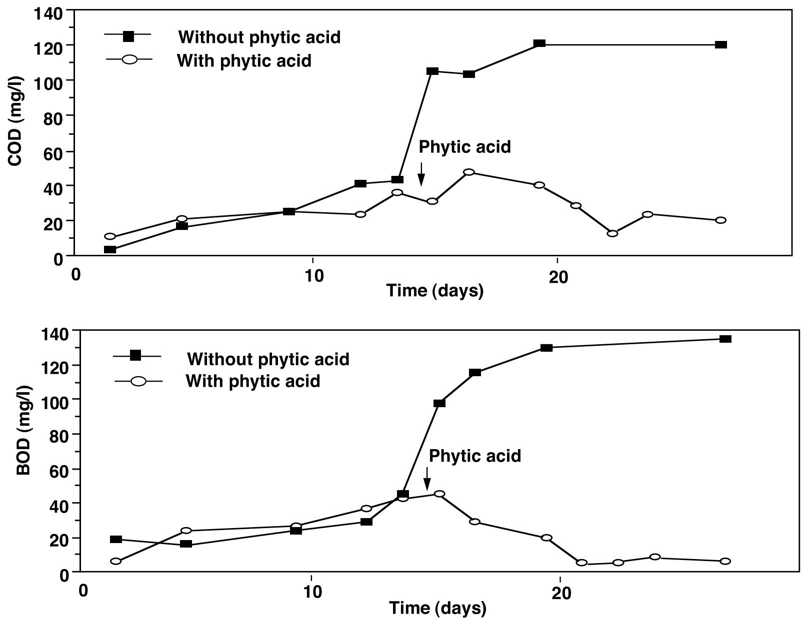

Fig. 7. Variations in COD and BOD in Effluents after Treatment before and after Phytic Acid Addition

Phytic acid (the quantity in 1 g of rice bran) was added five times every second day to the aeration tank after bulking had been confirmed by microscopic examination and SVI value.

on the growth of the effective microorganism was also studied on a laboratory scale using the experimental apparatus. First, 0.1 ml of 50% phytic acid (the quantity in 1 g of rice bran) was added five times every second day to the aeration tank, after bulking had been confirmed by microscopic examination and the SVI value. Figure 7 shows the variation in COD and BOD in the effluents before and after the addition of phytic acid. After the addition of phytic acid, both COD and BOD decreased in comparison with the control without phytic acid. As shown in Fig. 8, long, filamentous organisms were reduced immediately within 3 days after phytic acid addition. *Zoothamnium*, which is an effective microorganism, appeared within 6 days after phytic acid addition, and the effluent COD and BOD improved to the pre-

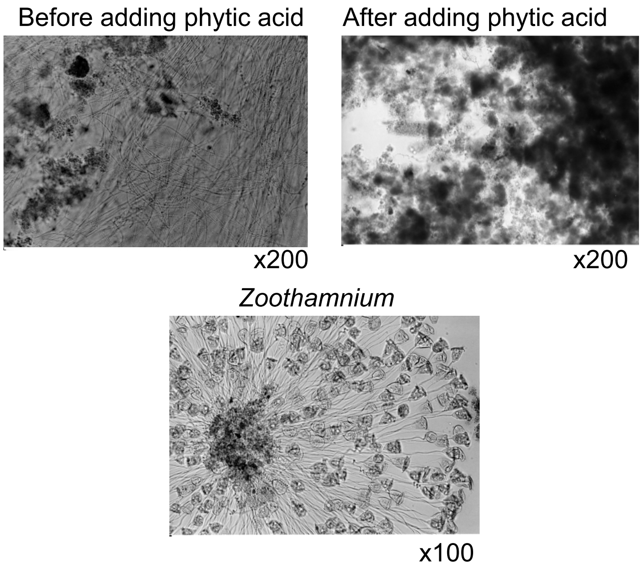

Fig. 8. Light Micrograph of Activated Sludge in the Aeration Tank before and after Phytic Acid Addition Addition

vious levels. These results show that phytic acid accelerates the growth of the effective microorganism.

Rice bran is a waste product in the process of making polished rice from brown rice and is very inexpensive, costing 1/100 of a commercial synthetic polymer. In addition, the use of rice bran is an effective utilization of waste. Taken together, the findings of this study suggested that the use of rice bran in the activated sludge process is an efficient and cost-effective method to prevent bulking.

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