CHAPTER X

CONCLUSIONS

Molasses-based distilleries are one of the most polluting industries generating large volume of colored wastewater. Thus, the aim of this dissertation was to explore the feasibility of using bacterial isolates for decolorization of the synthetic molasses-containing wastewater, with the ultimate aim of application for molasses-based distillery wastewater treatment. In this work, a bacterial consortium capable of decolorizing molasses wastewater was isolated from various sources in Thailand. Various parameters for maximal molasses wastewater decolorizing activity were also observed.

The present study started with the isolation of various molasses-decolorizing bacterial from different sources. After that, the identification of bacterial cultures by 16S rDNA based molecular approach were carried out. However, it clearly indicated that pure culture of bacterial isolate displayed a limited capability for decolorization of molasses wastewater in long-term treatment and it is necessary to improve its cultured conditions for further decolorization processes. Hence, in the Chapter 4, the molasses decolorizing bacterial consortium was isolated and in the Chapter 6, the artificial bacterial consortium MMP1 comprising of *Klebsiella oxytoca* (T1), *Serratia mercescens* (T2) and unknown bacterium DQ817737 (T4), was constructed. This bacterium consortium exhibited increased decolorization compared to that shown by any single isolate. This may be due to the enhanced effect of coordinated metabolic interactions on melanoidins decolorization. Then, the bacterial consortium MMP1 could be utilized for the decolorization of various kinds of melanoidins present in various industrial effluents including sugarcane and beet molasses wastewaters.

Environmental factors for example pH, temperature, aeration and nutrients play vital role in bacterial degradation process of industrial wastes, as the enzymes activity is greatly influenced by these environmental factors. Several studies have been carried out by groups of scientists to understand the role of various environmental factors in the degradation of melanoidins toward the maximum degradation and decolorization with different microbial species (Mohana et al., 2007; Kumar and Chandra, 2006; Sirianuntapiboon et al., 2004). In this study, the consortium showed the highest growth and melanoidins decolorization at the initial pH of 4 under low aeration condition. Thus, the consortium MMP1 might be suitably applied to the acid formation phase of conventional aerobic or anaerobic treatment systems of alcoholic distillery wastewater.

Also, it has been demonstrated that the aeration condition has a critical effect on melanoidins decolorization. In general, various aerobic bacterial isolates and

consortia that have been shown high melanoidins degradation efficiency are not suitable for treating effluent from molasses-based distillery industries in the absence of aeration. In contrast to other studies, the results presented herein have shown that color removal of the bacterial consortium under facultative and anaerobic conditions were higher than aerobic condition. Hence, the decolorization mechanisms of molasses wastewater by this bacterial consortium might result from 2 possible mechanisms. One was due to the color adsorption by bacterial cells and another might be due to the metabolism of bacterial cells under facultative and anaerobic conditions such as fermentation and anaerobic respiration. In addition, as shown in Chapter 7, the comparison of decolorization of consortium MMP1 with abiotic control has proved that the color removal for synthetic melanoidins-containing wastewater medium containing 2% (v/v) Viandox was due to biotic activity of bacteria but not to adsorption of color substances on cells surface.

Biological treatments employing fungi and bacteria have been investigated essentially to decolorize the distillery spent wash. In all cases, it was found necessary to supplement with additional nutrients as well as diluting the effluent for obtaining optimal microbial activity and eventually optimal results (Ohmomo et al., 1988; Sirianuntapiboon et al., 2004). Adding nutrients to biological treatment processes is one of the possible approaches to upgrading an existing facility in order to deal with increasing volumes and strengths of industrial wastewaters. Thus, the study in Chapter 8 was set up to investigate the limitation of decolorization of the synthetic melanoidins-containing wastewater medium by the constructed bacterial consortium MMP1. The results showed that the addition of nutrients had a favorable effect on decolorization of the used bacterial cells inoculated in fresh medium. This suggested that the decolorization of melanoidins ran parallel with the decomposition of nutrients. Therefore, nutrients could affect the growth and melanoidins decolorization of consortium MMP1. Furthermore, the addition of 0.5% (w/v) LB and B vitamins provided the similar results and their decolorization did not increase significantly relative to the reused culture medium without nutrient supplementation. Therefore, the limitation of decolorization efficiency of the bacterial consortium MMP1 in this study might not directly be due to the nutrient-limitation.

For process application, it was assumed that the constructed bacterial consortium MMP1 had the potential to be used as an inoculum for decolorization of melanoidins-containing wastewaters since its highest decolorization took place under the condition similar to the real distillery wastewaters. Thus, the laboratory-scale non-immersed bioreactor was designed, built and evaluated for the treatment the synthetic melanoidins-containing wastewater in the Chapter 9. In this context, a feasible system may be envisaged by coupling the degradation capability of bacterial

consortium MMP1 with inherent advantages of membrane bioreactor. The results obtained from membrane coupled bioreactor systems at different hydraulic retention times (HRT) of 40, 20 and 15 h indicated that COD removal efficiency was dependent of HRT. The operation with longer HRT has shown benefits for treatment of the synthetic melanoidins-containing wastewater. In general, bacterial concentration is an important parameter in performance as it represents the biomass concentration in the reactor; also increasing bacterial concentration implies increasing COD removal rate. In contrast, in this study, COD removal efficiency was not significantly affected by the increase in bacterial concentration. Moreover, the color and COD removal efficiency of the synthetic melanoidins-containing wastewater was relatively low due to the presence of recalcitrant organics and growth inhibiting substances (Satyawali and Balakrishnan, 2008; Chandra et al., 2008). The performance of a laboratory-scale MBR used in this study was compared with the existing wastewater treatment system as shown in Table 10.1. These results show that the color concentration of treated water still requires a post-processing wastewater treatment system in order to eliminate the remaining color, or a better understanding of the MBR operating conditions influence on the performance of the process.

Table 10.1 Performance of various membrane reactors for molasses distillery wastewater

Wastewaters	MBR Configuration	Materials	HRT	SRT	COD removal	Color removal	References
Shochu distillery wastewater	External MBR (EMBR)	Polysulfone molecular waight cut off 2,000 KDa.	NR	No discharged	98%	NR	Nagano et al., 1992
Brewery wastewater	Anaerobic digestion Ultrafiltration (ADUF)	Polyethersulfone 0.44 μm	19.2 h	NR	97%	NR	Ross and Strohwald, 1994
Wine Distillery	Anaerobic digestion Ultrafiltration (ADUF)	Polyethersulfone 0.44 μm	72 h	NR	93%	NR	
Simulated distillery wastewater	Submerged MBR (SMBR)	0.2 μm stainless steel	10 –30 h	NR	94.7%	NR	Zhang et al., 2006
Distillery wastewater	External MBR (EMBR) Hybrid nanofiltration Nanofiltration (NF) and Reverse Osmosis process	Commercial Nanofiltration and thin film composite polyamide RO in spiral wound	NR	NR	99.9%	80%	Nataraj et al., 2006
Synthetic melanoidins-containing wastewater	Side-stream MBR	0.14 μm mineral membrane (M14 Carbosep®)	40 h	50 days	25.5%	13.5%	This study

NR: Not reported

Recommendations for future molasses wastewater treatment

Considering the decolorization performances and COD removal efficiency of the bacterial consortium MMP1, biological treatment coupled with membrane technology cannot be absolute treatment of molasses-based distillery wastewater. Hence, there is a need to establish a comprehensive treatment approach involving all the technologies sequentially. Whatever the methods employed for treatment of effluent from molasses-based distillery industries, it can be concluded that in an ideal cost objective, the commercial treatment scheme should comprise a biological processes as the primary step followed by a physicochemical treatment.

The following recommendations are intended to provide insight into the molasses-based distillery wastewater treatment process to achieve consistent and high quality effluent suitable for environmental discharge.

- It is established that several microorganisms such as bacteria and fungi, especially in pure cultures, show a limited ability to decolorize the molasses-based distillery. Thus, a better understanding of the microbial activities responsible for the degradation of melanoidins and the interaction between pure cultures in the consortium would contribute to enhancing the efficiency of the overall treatment system.

- Most of the investigations on bacterial isolates that can result in both color and COD removal have been limited exclusively in laboratory scale experiment. The issues of appropriate system design and scale-up have rarely been addressed. In this context, treatment systems like membrane bioreactors that have lower sludge production can be considered. In addition, the minimizing of nutrient supplementation should be examined. These issues are particularly significant in the application field of molasses-based distillery wastewater treatment.

- The operations of membrane bioreactor for treatment of molasses-based distillery wastewaters are characterized by significant membrane fouling that limits its applicability. Membrane bioreactor can result in significant color removal. However, molasses distillery is a complex and multi-components wastewater that is known to cause membrane fouling. Moreover, the characteristics and structure of melanoidins (color-causing substances in molasses distillery) is still not fully understood. Thus, the understanding of the wastewater components which are primarily responsible for this phenomenon would contribute to an appropriate and efficient usage of the membrane bioreactor. In addition, the future trends in MBR process optimization would

involve the modeling of parameters affecting the performance of wastewater treatment.