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Effect of pH, Alkalinity and C: N Ratio During Anaerobic Digestion of Palm Oil Mill Effluent in Two-Phase Reactor with Food Waste as a Feedstock

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***Abstract*—Anaerobic digestion has stronger advantages other than alternatives method as it not requires energy for aeration purpose. To prevent the reactor failure, many factors need to be considered to maintain the performances of anaerobic digesters. Thus, the objective of this study was to investigate the effect of some parameters such as pH, alkalinity and carbon to nitrogen ratio towards anaerobic digestion of palm oil mill effluent (POME) with food waste in two-phase reactor was experimentally evaluated. The experiment was performed with three different ratio of palm oil mill effluent and food waste at a temperature of 45°C. The result shown that the range of pH obtained for all three ratios was 4.0 to 7.4. The value of alkalinity was between 8200 to 33000 mg/L meanwhile between 26.9 to 4.8 values of C:N ratio was obtained from the three different ratio of experiment conducted. The best ratio for pH recommended in this study was at a ratio 3 for reactor B because the optimum value of pH obtained for microbial growth compared to the other ratios. In term of C:N ratio, all three ratio for all reactor shown an acceptable value for C:N ratio although at the end of the process, the value of C:N ratio was decreased.**

***Keywords*—Anaerobic digestion; palm oil mill effluent; food waste; two-phase reactor**

INTRODUCTION

The production of crude palm oil has created environmental issues for the palm oil mill industry in Malaysia due to its polluting characteristics that generated liquid waste known as palm oil mill effluent (POME) [4, 11]. The characteristic of POME is thick brownish liquid with fine suspended solids, high biological oxygen demand, chemical oxygen demand, high solid concentration and acidity and pH ranging of 4-5 [17, 19].

The water used during processing of crude palm oil (CPO) is estimated about 5-7 tonnes for each tonnes of CPO produced. So, more than 50% of water wills ends up as POME [2]. Therefore, about 2.3-3.75 tonnes of POME will be generated for per tonnes of CPO production. Without a proper waste management implemented in palm oil mill, this huge quantity of POME will pollute the watercourses nearby the palm oil mills [14].

The current available alternative method for POME treatment are aerobic treatment [22], evaporation method [16] and membrane treatment system [1] but, anaerobic digestion has a stronger advantages other than alternative methods as it not require energy for aeration purpose [19]. To prevent the reactor failure, many factors need to be considered to maintain the performances of anaerobic digesters. The few major factors that greatly influence digester performances in POME treatment are pH, alkalinity and C: N ratio. Thus, the objective of this study was to evaluate the effects of these parameters toward anaerobic digestion of POME and food waste.

Food waste was used in this study as a feedstock during anaerobic digestion of POME in two-phase reactor. This is because, food waste which is putrefies can causes a leachate problem when it dumps at the landfill site. The physical and chemical characteristics of food waste include high organic content, high moisture content, high nitrogen content, loose physical structure and low carbon to nitrogen ratio [6, 13].

Methods and Materials

Feedstock and Inoculums Preparation of Anaerobic Reactors: Food waste as a feedstock was collected from stalls and restaurant near School of Environmental Engineering, UniMAP. The components of food waste include waste from food preparation such as uneaten rice and noodles, fish bond, chicken, egg shells fruits and vegetables. Food waste was prepared according to the group percentages which are rice and noodles (45%), fish bond and egg shells (30%) and vegetables (20%) for one kilogram of total weight in wet basis. Then, food waste was blended with one liters of water according to the ratio of food waste. After that, the blended food waste was mixed together with palm oil mill effluent (POME). POME as inoculums used in this study was obtained from holding pond of palm oil factory which

are Malpom Sdn. Bhd, Nibong Tebal Pulau Pinang. It has been acclimatized at 45^{o}C in the reactors for a period of one week.

Experimental Setup of Anaerobic Solid-Liquid Reactor: A laboratory double phase reactor which is Anaerobic Solid-Liquid Reactor (ASLR) was conducted in a batch mode for 60 days. The ASL reactor consists of acidification reactor and methanogenic reactor. The acidification reactor was designed with Inner Diameter (ID) of 140mm with total effective volume of 5 liter and the methanogenic reactor with working volume of 3 liter. Figure 2.1 shows the ASL reactor.

Three runs of experiment with different ratio of feedstock and inoculums were conducted. The three working ratio used include 1kg food waste to 2L inoculums (Ratio 1), 2kg food waste to 2L inoculums (Ratio 2) and 2kg food waste to 1L inoculums (Ratio 3). After three days of acclimatization, the acidogenic reactor was connected to the methanogenic reactor to establish the ASL reactor. About 400ml leachate from acidification reactor was feed into the methanogenic reactor every three days. Nitrogen gas was injected every time when feeding and sampling the sample in the methanogenic reactor. Both reactors were operated in the waterbath instrument of 45^{o}C. Sample taken were characterize for pH, alkalinity and C:N ratio. The pH value of the sample was measured immediately after sampling by using a portable electrochemical pH meter. Alkalinity was measured according to APHA 2005 and analysis for C: N ratio was done by using CHONC Analyzer (Series II CHNS/O Analyzer 2400).

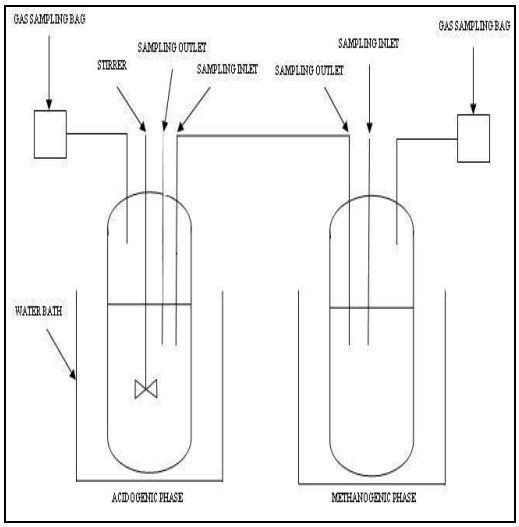
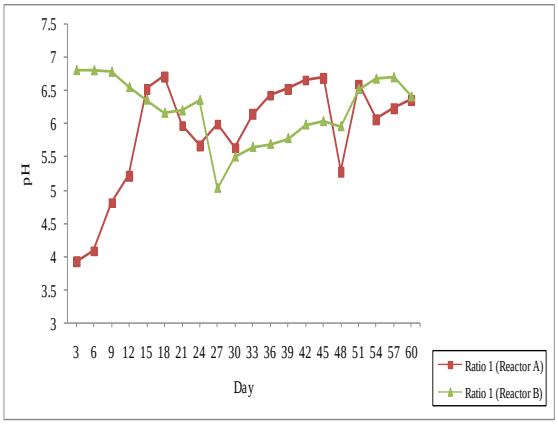


Figure 2.1 Schematic diagram of ASL reactor

Results and Discussions

The Effect of pH during the Digestion Process



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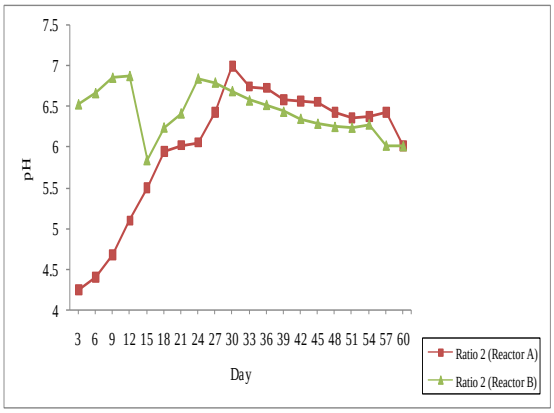

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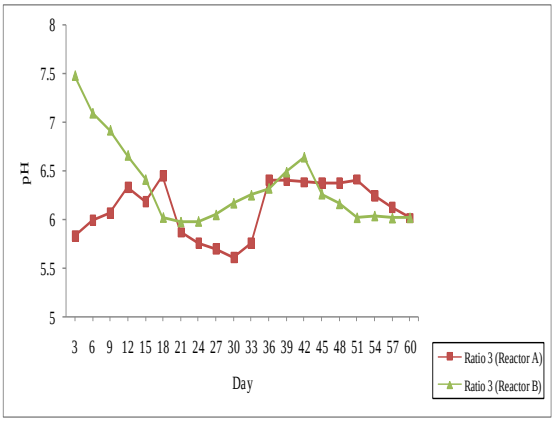


(c)

Figure-1: Graph pH changes for three ratios used during the digestion process; (a) ratio 1, 1kg food waste: 2L inoculums, (b) ratio 2, 2kg food waste: 2L inoculums, (c) ratio 3, 2kg food waste: 1L inoculums

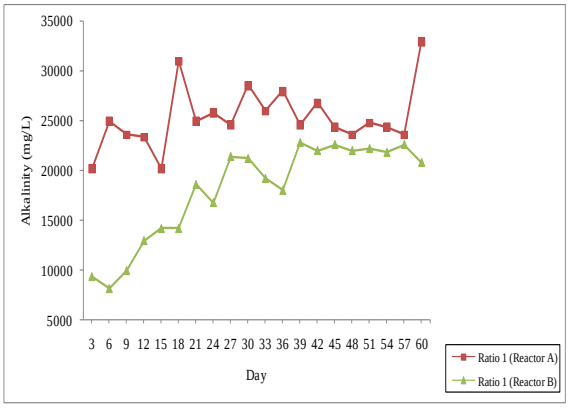
Fig. 4.1 shows the pH values for all three ratios involved in two reactors during anaerobic digestion of food waste and palm oil mill effluent (POME). The pH values for ratio 1 (1kg food waste: 2L inoculums) was in a range of 4-6.8 for both reactors A and B. The pH values of both reactors A and B for ratio 2 (2kg food waste: 2L inoculums) was in a range of 4-7.01. For

ratio 3 (2kg food waste: 1L inoculums), the pH value recorded was about 5.6-7.4 for reactors A and B.

Rajaonahy et al., (2016) [20] stated that through the process of anaerobic digestion, the pH plays an important role in the growth of microorganisms. The optimum pH for microbial growth is between 6 and 7. pH value lower than 4 and higher than 9.5 are not tolerable [8]. Methanogenesis is also favoured at pH between 6 and 7 [7]. When pH in the digester deviates from the optimum value, the methanogenic activity will decrease [19].

The pH value in this study was fluctuated because of the fermentation process happen during the digestion process. At the end of the process, the value of pH for all ratio of reactor B was drop. This indicated that the acidic intermediate like volatile fatty acid (VFA) was produced in a considerable quantity causing decreased in the pH value. The biogas methane producing methanogens will also be affected by the accumulation of VFA as a result from the lower of pH value [20, 21].

The Effect of Alkalinity during the Digestion Process



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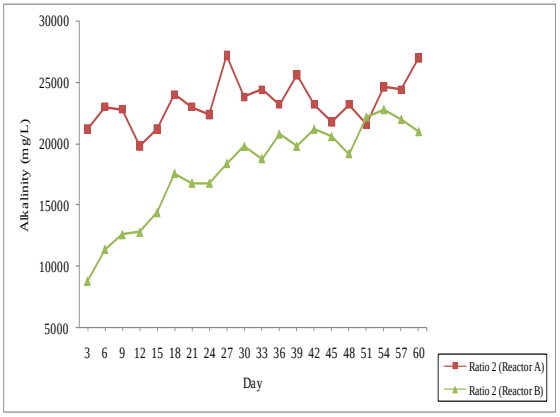

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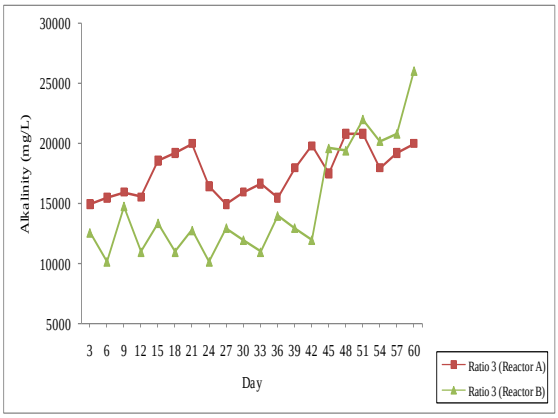

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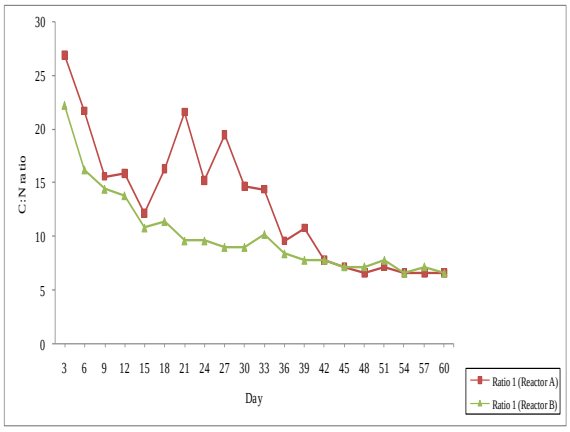
Figure-2: Graph alkalinity changes for three ratios used during the digestion process; (a) ratio 1, 1kg food waste: 2L inoculums, (b) ratio 2, 2kg food waste: 2L inoculums, (c) ratio 3, 2kg food waste: 1L inoculums

The result of alkalinity during the anaerobic digestion of POME with food waste was showed in Fig. 4.2. The alkalinity values for ratio 1 (1kg food waste: 2L inoculums) was in a range of 8200 to 33000 mg/L for both reactors A and B. The alkalinity values of both reactors A and B for ratio 2 (2kg food waste: 2L inoculums) was in a range of 8800 to 27200 mg/L. For ratio 3 (2kg food waste: 1L inoculums), the alkalinity value recorded was about 10200 to 26000 mg/L for reactors A and B.

The alkalinity also plays an important role during the digestion process. By buffering the acidity derived from the acidogenesis process, alkalinity important pH controlling role in the anaerobic treatment process [8]. Alkalinity also observed during the process to increases the value of carbon to nitrogen ratio of the feed thereby to lead a better process stability [21]. Besides that, the value of alkalinity need to be maintained by recirculation of treated effluent to the digester as a purpose to control the level of fatty acid in the system [17].

The Effect of C:N ratio during the Digestion Process



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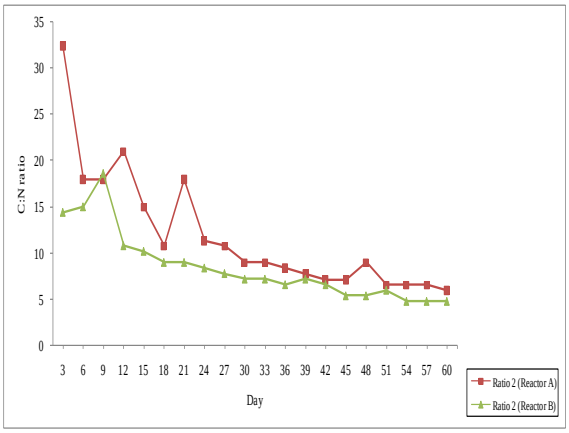

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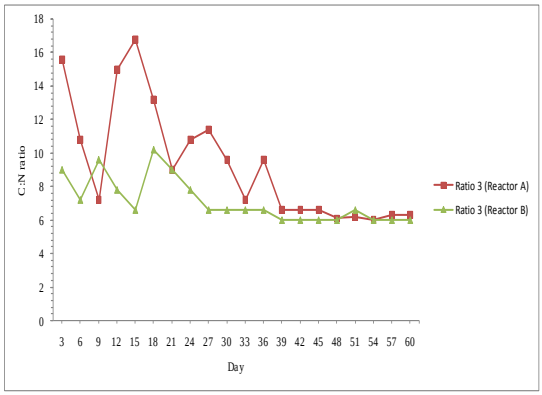

(c)

Figure-3: Graph pH changes for three ratios used during the digestion process; (a) ratio 1, 1kg food waste: 2L inoculums, (b) ratio 2, 2kg food waste: 2L inoculums, (c) ratio 3, 2kg food waste: 1L inoculums

Figure 4.3 demonstrated the result for C:N ratio for all ratios in each reactor during the digestion process. The C:N ratio values for ratio 1 (1kg food waste: 2L inoculums) was in a range of 22.9 to 6.6 for reactor A and in a range of 22.2 to 6.6 for reactor B. The C:N ratio values for reactor A was 32.4 to 6 and 14.4 to 4.8 for reactor B for the ratio 2 (2kg food waste: 2L inoculums). For ratio 3 (2kg food waste: 1L inoculums), the C:N ratio value recorded was about 15.6 to 6.3 for reactor A and for reactor B in a range of 9 to 6.

During the anaerobic digestion, the C:N ratio in the organic matter plays a crucial roles [12]. To achieved a better process stability during the digestion process, the value of C:N ratio through the process need to be increases [23]. The only factor that causing a limiting anaerobic digestion of organic wastes was the unbalanced nutrients content [5]. All the values of nutrient content for all reactors shown were decreased at the end of the digestion process. This is happen because microorganisms in the POME has insufficient nutrients mainly carbon source [18].

The value of C:N ratio obtained in this study was not achieved an optimal value, since the optimal value of C:N ratio for anaerobic degradation of organic waste was 20-35 [10]. Li et al., (2011) [15] also mentioned that the optimum condition of C:N ratio for anaerobic digestion was in a range of 20-30. However, some researcher stated that the digestion process also proceeded well at a low C:N ratio of 15-20 [25, 26]. So, the feedstock and inoculums during anaerobic digestion will influence the optimum C:N ratio obtained during the process [24].

CONCLUSION

From the research done, it can be conclude that pH, alkalinity and carbon to nitrogen ratio was some of the important parameters to be evaluated during the digestion process especially for methane production. The pH was important for the growth of microorganisms during the anaerobic digestion process. Alkalinity directly related to the pH in which important pH controlling role by buffering the acidity derived from the acidogenesis process in anaerobic treatment process. Carbon to nitrogen ratio was important because it plays a crucial role anaerobic digestion in the organic matter. The best ratio for pH recommended in this study was at a ratio 3 for reactor B because the value of pH obtained is between 6-7 in which, this is the optimum pH for microbial growth compared to the other ratios. In term of C:N ratio, all three ratio for all reactor shown an acceptable value for C:N ratio although at the end of the process, the value of C:N ratio was decreased. However, it can be increased added some supplementary carbon source into the POME sample.

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REFERENCES

[1] Ahmad, A.L., Chong, M.F. & Bhatia,S. Mathematical modeling of multiple solutessystem for reverse osmosis process in palm oil mill effluent (POME) treatment.*Chemical Engineering Journal* **132**, 183–193, 2007.

[2] Ahmad, A.L., Ismail, S. & Bhatia, S. Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination*, **157**, 87-95, 2003

[3]APHA (Standard Methods for Examination of Water and Wastewater, 21st edition,American Public Health Association, Washington D.C., USA, 2005.

[4] Borja,R. & Banks, C.J. Comparison of an anaerobic filter and an anaerobic fluidized bed reactor treating palm oil mill effluent. *Process Biochemistry,* **30**: 511–21, 1995.

[5] Cuetos, M.J., Gomez, X., Otero, M. & Moran, A. Anaerobic digestion of solid slaughterhouse waste (SHW) at laboratory scale: influence of co-digestion with the organic fraction of municipal solid waste (OFMSW). *Biochemistry Journal,* **40**, 99 106, 2008.

[6] Chang, J. I. & Hsu, T.-E. Effects of compositions on food waste composting. *Bioresource Technology,* ***99*** (17), 8068-8074, 2008.

[7]Chugh, S., Clarke, W., Pullammanappallil, P. & Rudolph, V. Effect of recirculated leachate volume on MSW degradation. *Waste Management Resources,* **16**(6), 564–73, 1998.

[8] Gerardi, M.H. Wastewater Bacteria. Wiley-Interscience, New Jersey. pp. 19–31 in Poh, P.E. & Chong, M.F. 2009. Development of anaerobic digestion methods forpalm oil mill effluent (POME) treatment. *Bioresource Technology,* **100**, 1-9, 2006.

[9] Gerardi, M.H. The microbiology of anaerobic digesters. John Wiley and Sons Inc., New Jersey, pp. 91-118, 2003.

[10]Guermoud, N., Ouagjnia, F., Avdelmalek, F., Taleb, F. & Addou, A. Municipal solid waste in Mostagnem city (Western Algeria). *Waste Management*, **29**, 896–902, 2009.

[11] Ji, C.H., Eong, P.P., Ti, T.B., Seng, C.E. & Ling, C.K. Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. *Renewable and Sustainable Energy Reviews,* **26**, 717-726, 2013.

[12] Khalid, A., Arshad, M., Anjum, M., Mahmood, T. & Dawson, L. The anaerobic digestion of solid organic waste. *Waste Management,* **31**, 1737-1744, 2011.

[13] Kumar, M., Ou, Y.-L. & Lin, J.-G. Co-composting of green waste and food waste atlow C/N ratio. *Waste Management,* ***30***(4), 602-609, 2010.

[14] Lam, M.K. & Lee, K.T. Renewable and sustainable bioenergy production from palmoil mill effluent (POME): win-win strategies toward better environmental protection.*Biotechnology Advances*, **29**, 124-141, 2011.

[15] Li. Y., Park. S.Y. & Zhu. J. Solid-state anaerobic digestion for methane productionfrom organicwaste. *Renewable Sustainable Energy Review,* **15**,821–6, 2011.

[16] Ma, A.N., Tajima, Y., Asahi, M. & Hanif, J. Effluent treatment – evaporation method. *PORIM Engineering News*, **44**, 7–8, 1997.

[17] Najafpour, G.D., Zinatizadeh, A.A.L., Mohamed, A.R., Hasnain Isa, M. & Nasrollahzadeh,H. High-rate anaerobic digestion of palm oil mill effluent in an upflowanaerobic sludge-fixed film bioreactor. *Process Biochemistry,* **41**, 370–379, 2006.

[18] Nurliyana. M.Y., H'ng. P.S., Rasmina. H., Umi Kalsom. M.S., Chin. K.L., Lee. S.H., Lum.W.C. & Khoo. G.D. Effect of C/N ratio in methane productivity andbiodegradability during facultative co-digestion of palm oil mill effluent and emptyfruit bunch. *Industrial Crops and Products,* **76**,409-415, 2015.

[19] Poh, P.E., & Chong, M.F. Development of anaerobic digestion methods for palm oil mill effluent (POME) treatment. *Bioresource Technology*, **100**, 1-9, 2009.

[20]Rajaonahy, M.R., Rakotondramiarana, H. T. & Rakotoarisoa, L.L. Experimental investigation of anaerobic co-digestion of some organic wastes in Madagascar. *Journal of Multidisciplinary Engineering Science and Technology,* B(1), 1-7, 2016.

[21] Tanimu, M.I., Mohd Ghazi, T.I., Harun, R.M. & Idris, A. Effect of carbon tonitrogen ratio of food waste on biogas methane production in a batch mesophilic anaerobic digester. *International Journal of Innovation, Management and Technology,* B(2), 1-4, 2014.

[22] Vijayaraghavan, K., Ahmad, D. & Abdul Aziz, M.E. Aerobic treatment of palm oil mill effluent. *Journal of Environmental Management,* **82**, 24–31, 2007.

[23] Zhang. Y., Charles. J.B. & Heaven. S. Co-digestion of source segregated domestic food waste to improve process stability. *Bioresource Technology,* **114**(1), 168-178, 2012.

[24] Zhang. C., Su. H., Baeyens. J. & Tan. T. Reviewing the anaerobic digestion of food waste for biogas production. *Renewable and Sustainable Energy Reviews,* **38,** 383-392, 2014.

[25] Zhang. C., Xiao. G., Peng. L., Su. H. & Tan. T. The anaerobic co-digestion of food waste and cattle manure. *Bioresource Technology,* **129**,170–6, 2013.

[26] Zhong. W., Chi. L., Luo. Y., Zhang. Z, Zhang. Z. & Wu. W.M. Enhanced methane production from Taihu Lake blue algae by anaerobic co-digestion with corn straw in continuous feed digesters. *Bioresource Technology,***134**,264–70,2013.