Effect of Human Urine during Production of Methane from Boiled Rice

Subodh Kumar Sau[1], Tapas Kumar Manna[2], Apurba Giri[3], Prasanta Kumar Nandi[4]

[1]Department of Chemistry, Bengal Engineering and Science University, Shibpur -711103, Howrah, West Bengal, India

[2]Department of Chemical Engineering, Haldia Institute of Technology, Haldia – 721657, Purba Medinipur, West Bengal, India

[3]Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur -721302, India

[4]Department of Chemistry, Bengal Engineering and Science University, Shibpur -711103, Howrah, West Bengal, India

Abstract: ***Boiled rice waste is a polluted organic substance. It is necessary to control the environmental pollution and bio-energy recovery from this waste simultaneously. Human urine is unhygienic to the environment whereas it can be utilized as a biocatalyst in digested boiled rice under the pH range of 6.8-7.2 for the enhancement of production of biogas at 30°C. In this study boiled rice was predigested with bakhar (mixture of different specific plant roots) and different levels of human urine (150 ml, 200 ml and 250 ml) were added in different batches. It was found that the maximum production of CH_4 (0.011126 m^3/kg boiled rice) was observed by addition of 250 ml of urine. The mathematical model equation (Chen and Hasimoto equation) on biomethanation determined the maximum specific growth rate and kinetic parameter.***

Keywords: Bakhar, Biogas, Boiled rice, Human urine, Methane

Nomenclature
B_u = ultimate methane yield (m^3/kg boiled rice)
B = methane yield (m^3/kg boiled rice)
k = kinetic parameter
μ_m = maximum specific growth rate (day^{-1})
Φ= retention time (days)

1. Introduction

Biogas is the only cheap alternative renewable source of energy which can be made available in rural areas. It is composed mainly of CH_4 and CO_2 [1]. Methane has potential uses viz. as fuel, electricity generation, urea production etc. [2, 3]. However, CH_4, which is emitting in the environment from organic wastes, is a green house gas with greater global warming [4, 5]. Anaerobic digestion is the process which breaks down the organic matter to simple chemical component using four different stages [6, 7, 8, 9]. These are hydrolysis, acidogenesis, acitogenesis and methanogenesis. In the fourth stage acetate is converted to CH_4 and CO_2 [10, 11, 12]. Various works have been done using agricultural and animal wastes to produce biogas [13, 14, 15]. Anaerobic digestion of food waste to enhance biogas was done by Dearman and Bentham [16]. Boiled rice from domestic, restaurant, hospital sources are polluting the environment. Human urine is also unhygienic to open environment where as, it can be act as a potential biocatalyst during biogas production. However, only one work has been reported to produce biogas from organic wastes by utilizing human urine [17]. Bakhar which is a mixture of different plant roots (*Akanbindi, Kendu, Fern, Chandua, Chaulia & Asan*), is used as pellet form in the fermentation of boiled rice to prepare beverages (viz. *Handia*) by the tribal of Orissa state in India [18]. So this *bakhar* can be used to predigest the boiled rice waste during biogas production. Several authors reported that during continuous anaerobic digestion to evaluating kinetic parameters, mathematical model equation like Chen and Hasimoto equation was very suitable [19, 20, 21, 22].

So, the objective of the present work was to enhance the production of methane from boiled rice by predigesting the boiled rice using *bakhar* followed by anaerobic digestion of the mixture using different levels of urine as a biocatalyst. The kinetic model of biomethanation was evaluated using Chen and Hasimoto equation.

2. Material and Methods

Proximate analysis of rice in terms of moisture, fat, protein, ash content were determined according to AOAC (1980) while the carbohydrate content of samples was obtained in form of difference between 100 and the sum of moisture, protein, fat and ash values [23]. The proximate nitrogen composition of human urine was determined following the method Kirchmann and Pettersson [24].

In the present investigation 100 g of boiled rice, 3 g of *bakhar* (purchased from local market) were mixed and the mixture was allowed to partial decomposition with addition of 100 ml water. The decomposed waste was then introduced into the digester (a conical glass beaker, 500 ml capacity; Figure 1). Human urine was added as 150 ml, 200 ml and 250 ml human urine in three different sets. The pH of solution of each set was maintained in between 6.8 to 7.2 by adding required amount of NaOH. The digester was sealed and made air tight. The anaerobic digestion was carried out at 30°C and the gas generated in the digester was passed through a pipe to the gas burette and collected in the burette by downward displacement of water [25]. Gas production was calculated from daily reading of the gas burette.

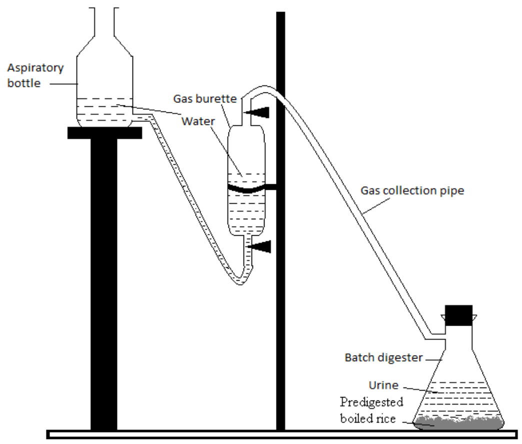


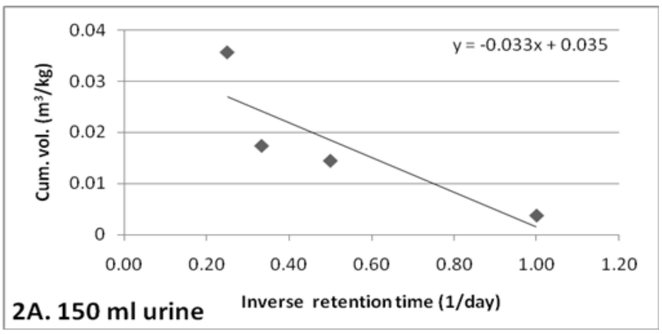
Figure 1: Schematic diagram of digester set-up for boiled rice waste

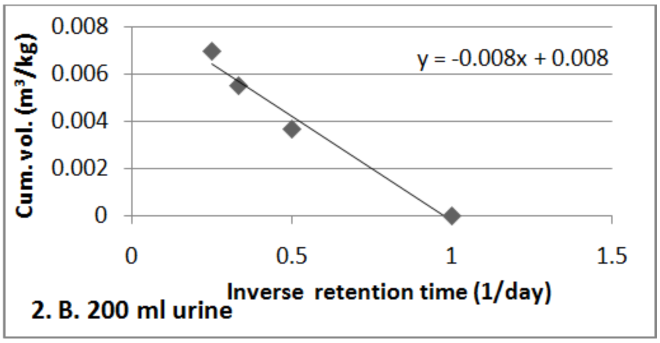
Syringe method [26] was used for the measurement of amount of CH_4 and CO_2 in biogas production. A syringe fitted with flexible tube and diluted NaOH solution was used for CO_2 percentage estimation since NaOH absorbs CO_2 but does not absorbs methane.

3. Results and Discussion

Average proximate composition of boiled rice was moisture - 66.31%, carbohydrate – 30.33%, protein – 2.7%, fat – 0.25%, ash – 0.41% and the proximate nitrogen composition of human urine was total N: 2.62 g/l; $NH_4{}^+$ -N: 1.71 g/l; NH_3, aq –N: 0.75 g/l; amino acid –N: 0.12 g/l; NO_3^- –N: 46 µg/l; NO_2^- -N: 21 µg/l.

It was found that the maximum production of biogas as well as CH_4 (0.011126 m^3/kg boiled rice) was observed by addition of 250 ml of urine. Figures 2A, 2B, 2C are showing the variation of cumulative CH_4 yield against inverse retention time in day^{-1} for 150 ml, 200 ml, and 250 ml urine, respectively. From these graphs the ultimate CH_4 yield (Bu) is calculated at inverse retention time (day^{-1}) = 0. It was found that the graphical analysis is more significant as Chen and Hasimoto [27] assumed a linear relationship between the cumulative CH_4 yield (m^3/kg) and inverse retention time in day^{-1}. It was observed that Bu was maximum for 150 ml urine at 30°C.





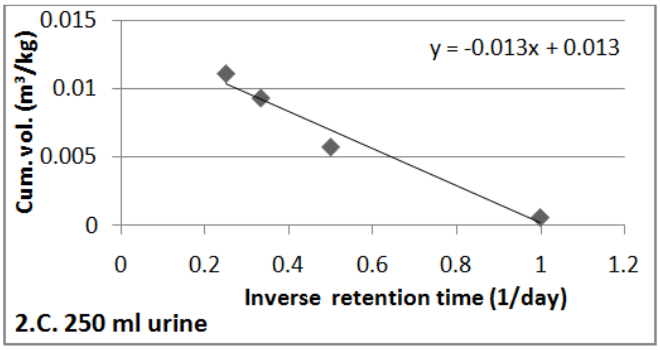
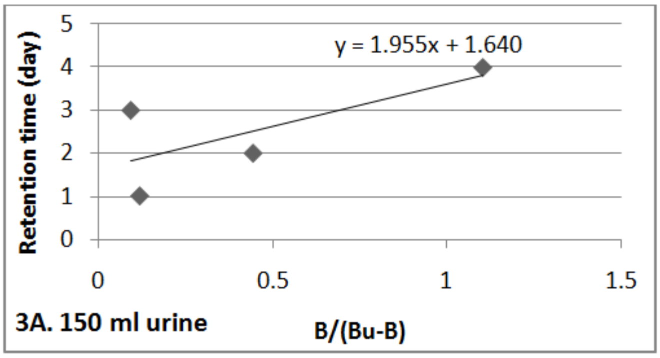
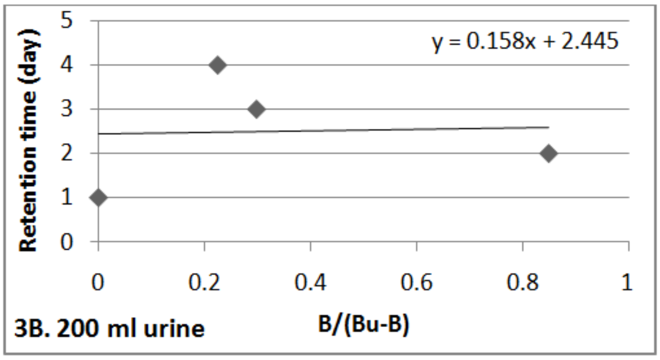


Figure 2: Plot of cumulative methane yield against inverse retention time at different levels of urine for boiled rice waste

Figures 3A, 3B, 3C are showing the plot of variation of retention time in day vs. B/(Bu-B) for the above mentioned volume of urines.





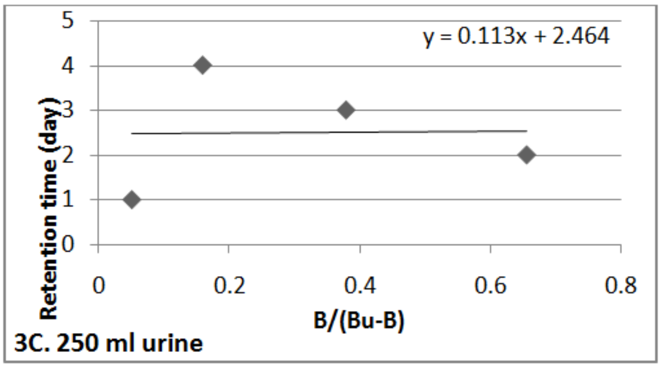


Figure 3: Plot of B/(Bu-B) against retention time at different levels of urine for boiled rice waste

According to Chen and Hasimoto (1981) model equation

$$\Phi = \frac{1}{\mu_m} + \frac{k}{\mu_m} \cdot \frac{B}{(Bu - B)}$$

Data were fitted in the above equation. However comparing with the model equation of Chen and Hasimoto [27], the value of maximum specific growth rate (μ_m) and kinetic parameter (k) was determined from the intercepts ($1/\mu_m$) and slopes (k/μ_m), respectively. It was noticed that μ_m and k were gradually decreased with increasing the volume of urine, whereas the Bu initially decreased and then increased slowly (Table 1). Similar μ_m values were obtained by Banerjee and Biswas [22].

Table 1: Results of experimental parameters for different level of urine for biomethanation of boiled rice waste

Vol. of urine (ml)	*Bu (m^3/kg boiled rice)*	*μ_m*	*k*
150	0.035	0.609756	1.192073
200	0.008	0.408998	0.064622
300	0.013	0.405844	0.04586

Volume of urine vs. Bu, µm and k were plotted in Figures 4, 5 and 6, respectively. By graphical analysis it was observed that all the three variation of curves were non-linear in nature. Bu was independent in the model where as μ_m was dependent in the model used and μ_m represents the maximum microorganism growth rate which indicates maximum CH_4 yield.

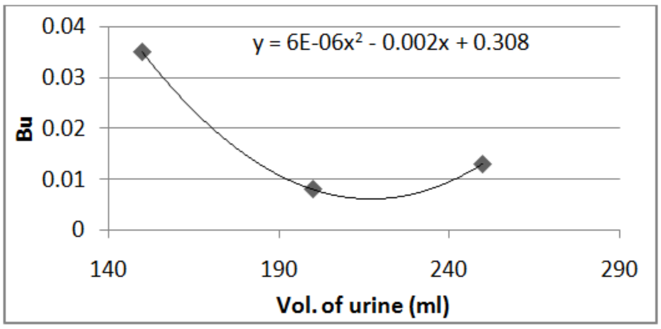


Figure 4: Plot of Bu against different levels of urine

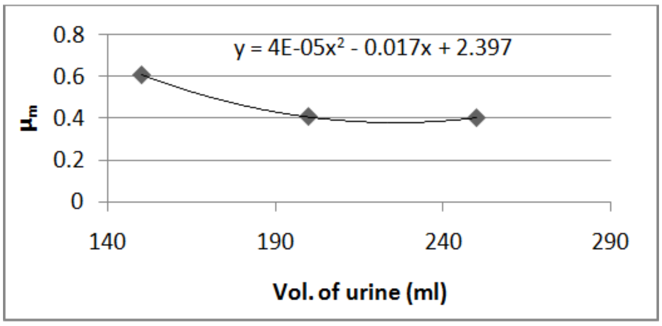


Figure 5: Plot of μ_m against different levels of urine

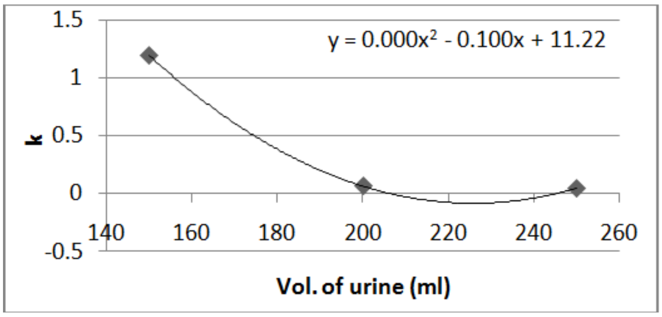
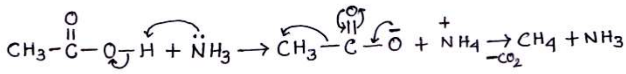


Figure 6: Plot of k against different levels of urine

The pH of boiled rice was decreased after pre-digestion. The acidity was well balanced and acted as buffer by the addition of human urine. pH was varied between 6.8 to 7.2. Similar observation was reported by Satyanarayana et al. [28]. The pH increased due to released of NH_4^+ ion by the deamination of amino acids and presence of NH_4^+ ion in urine. The optimum range of C: N ratio was 25±2.1 [29] for maximum yield of biogas as well as CH_4. Carbon (in carbohydrate) and nitrogen (in protein) were the main nutrients for anaerobic bacteria. Carbon supplied energies; nitrogen was needed for building up the cell structure. A too high C: N ratio means lack of nitrogen while too low value of C: N ratio leads to increase CH_4 production [30].

Anaerobic digestion was performed using human urine only, without adding boiled rice but no biogas was produced. So it can be concluded that here urine acted as a biocatalyst. A similar finding was observed by Haque and Haque [17] who enhanced 30% production of biogas by addition of human urine. The possible mechanism of decarboxylation of acetic acid by human urine has given below.

$$\text{Urine} \xrightarrow{\text{deamination}} NH_4$$



Urea is mainly excreted into urine via kidney. The nitrogen of amino acids is removed as urea. Normally a healthy adult person excreted about 15 g of nitrogen per day; 95% of this nitrogen is exerted as urinary urea. The amino groups of amino acids are ultimately removed and act as ammonia. This ammonia is highly toxic and is ultimately converted into urea. Normally urine is acidic. If the urine is kept exposed to atmosphere, it splits and ammonia gets released and thus stored urine becomes alkaline. Ammonia acts as a catalyst. The ammonia acts as a weak base which can readily abstract acidic H from acetic acid to form ammonium and acetate ion. The acetate ion is decarboxilated and methyl carbon ion is protonated to produce methane and ammonia. Due to pH in between 6.8 to 7.2, biogas slurry which is enriched in N, P, K can be used as biofertilizer [17, 31].

4. Conclusions

The present study provided some vital information regarding the catalytic effect of urine on the production of biogas from boiled rice. Maximum biogas as well as methane yield was observed from boiled rice by addition of 250 ml urine in 100 g boiled rice. Kinetic model of biomethanation was showing that maximum μ_m and k value were observed from boiled rice by the addition of 150 ml urine. It was found that the variation of volume of urine with Bu, μ_m and k exhibited non linear relationship. Ultimate CH_4 yield decreased initially followed by increased as the level of urine addition increased.

References

[1] Andersson, F.A.T., Karlsson, A., Svensson, B.H., Ejlertsson, J. 2004. Occurrence and abatement of volatile sulfur compounds during biogas producetion. J. Air Waste Manage. Assoc. 54(7), 855-861.
[2] Themelis, N.J., Ulloa, P.A. 2007. Methane generation in landfills. Renew. Energ. 32(7), 1243-1257.
[3] Thauer, R.K., Shima, S. 2008. Methane as fuel for anaerobic microorganisms. Ann. NY. Acad. Sci. 1125(1), 158-170.
[4] Jorgenson, A.K. 2006. Global warming and the neglected greenhouse gas: A cross-national study of the social causes of methane emissions intensity, 1995. Soc. Forces 84(3), 1779-1798.
[5] Howarth, R.W., Santoro, R., Ingraffea, A. 2011. Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change 106(4), 679-690.
[6] Chen, Y.R., Varel, V.H., Hashimoto, A.G., Methane production from agricultural residues. A short review, J. Ind. Eng. Chem. 19 (12) (1980) 471-477.
[7] Hashimoto, A.G., Chen, Y.R., Varel, V.H. 1981. Theoretical aspects of anaerobic fermentation: state of the art. In: Livestock waste: a renewable resource. Proceedings of the 4th International Symposium on Livestock Wastes. American Society of Agricultural Engineers, St Joseph, Michigan, pp. 86–91.
[8] Sreekrishnan, T., Kohli, S., Rana, V. 2004. Enhancement of biogas production from solid substrates using different techniques - a review. Bioresource Technol. 95(1), 1-10.
[9] Ward, A.J., Hobbs, P.J., Holliman, P.J., Jones, D.L. 2008. Optimisation of the anaerobic digestion of agricultural resources. Bioresource Technol. 99(17), 7928-7940.
[10] Klass, D.L. 1984. Methane from anaerobic fermentation. Science(Washington) 223(4640), 1021-1027.
[11] Weiland, P. 2006. Biomass digestion in agriculture: a successful pathway for the energy production and waste treatment in Germany. Eng. Life Sci. 6(3), 302-309.
[12] Yen, H.W., Brune, D.E. 2007. Anaerobic co-digestion of algal sludge and waste paper to produce methane. Bioresource Technol. 98(1), 130-134.
[13] Akinbami, J.F.K., Ilori, M., Oyebisi, T., Akinwumi, I., Adeoti, O. 2001. Biogas energy use in Nigeria: Current status, future prospects and policy implications. Renewable Sustainable Energy Rev. 5(1), 97-112.
[14] Demirbas, M., Balat, M. 2006. Recent advances on the production and utilization trends of bio-fuels: A global perspective. Energ. Convers. Manage. 47(15), 2371-2381.
[15] Lansing, S., Botero, R.B., Martin, J.F. 2008. Waste treatment and biogas quality in small-scale agricultural digesters. Bioresource Technol. 99(13), 5881-5890.
[16] Dearman, B., Bentham, R. 2007. Anaerobic digestion of food waste: Comparing leachate exchange rates in sequential batch systems digesting food waste and biosolids. Waste Manage. 27(12), 1792-1799.
[17] Haque, M.S., Haque, N.N. 2006. Studies on the effect of urine on biogas production. Bangladesh J. Sci. Ind. Res. 41(1), 23-32.
[18] Dhal, N.K., Pattanaik, C., Reddy C.S. 2010. Bakhar starch fermentation – A common tribal practice in Orissa. Indian J. Tradi. Knowl. 9(2), 279-281.
[19] Mata-Alvarez, J., Llabres, P. 1988. A kinetic study of the anaerobic digestion of piggery waste using down-flow stationary fixed film reactors. Appl. Microbiol. Biot. 28(3), 311-315.
[20] Math-Alvarez, J., Mtz-Viturtia, A., Llabrés-Luengo, P., Cecchi, F. 1993. Kinetic and performance study of a batch two-phase anaerobic digestion of fruit and vegetable wastes. Biomass Bioenerg, 5(6), 481-488.
[21] Borja, R., Alba, J., Garrido, S., Martinez, L., Garcia, M., Incerti, C., Ramos-Cormenzana, A. 1995. Comparative study of anaerobic digestion of olive mill wastewater (OMW) and OMW previously fermented with *Aspergillus terreus*. Bioprocess Biosyst Eng. 13(6), 317-322.
[22] Banerjee, S., Biswas, G. 2004. Studies on biomethanation of distillery wastes and its mathematical analysis. Chem. Eng. J. 102(2), 193-201.
[23] AOAC 1980. Official Methods of Analysis. 11th edition. Washington DC. Association of Analytical Chemists, USA
[24] Kirchmann, H., Pettersson, S. 1994. Human urine-chemical composition and fertilizer use efficiency. Nutr. Cycl. Agroecosys. 40(2), 149-154.
[25] Itodo, I., Lucas, E., Kucha, F. 1992. The effects of media material and its quantity on biogas yield. Nig. J. Renewable Energy 3(1), 45-49.
[26] Vij, S. 2011. Biogas production from kitchen waste & to test the quality and quantity of biogas produced from kitchen waste under suitable conditions. B Tech thesis, National Institute of Technology Rourkela, Orissa, India.
[27] Chen, Y.R, Hashimoto, A.G. 1981. Energy requirements for anaerobic fermentation of livestock wastes, In: Livestock wastes: a renewable resource, Proceedings of the 4th International Symposium on Livestock Wastes. American Society of Agricultural Engineers, St. Joseph, Michigan, pp. 117.
[28] Satyanarayan, S., Murkute, P. 2008. Biogas production enhancement by *Brassica compestries* amendment in cattle dung digesters. Biomass Bioener. 32 (3), 210-215.

[29] Fulford, D. 1988. How biogas works, running a biogas programme: A handbook. Intermediate Technology Publications, London. pp. 36.
[30] Singh, R., Mandal, S. 2011. The utilization of non-edible oil cake along with cow dung for methane-enriched biogas production using mixed inoculum. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33 (5), 449-458.
[31] Rajasekaran, P., Selvakumar, T., Sivaraman, G., Stephen Rapheal, V., Shanmugam, S., Sathish Kumar, T., Thanikal, J. V. 2008. Utilization of oil cakes for biogenesis of methane. Advanced Biotech. 7 (3) 25-27.

Author Profile

Subodh Kumar Sau received the B.Sc. and M.Sc. degrees from Calcutta University and IIT Kharagpur, respectively. His areas of research work are Glucose production from waste raw potato, Hepatobiliary diagnosis using 99m technetium based chellate, studies on the effective utilization of agricultural wastes etc. At present he is perusing Ph.D. in Chemistry at Bengal Engineering and Science University, Shibpur, Howrah

Tapas Kumar Manna received the B. Tech. degree from Calcutta University, Kolkata and both M. Tech. and Ph.D. degrees from IIT Kharagpur in Chemical Engineering; His areas of research work are Reaction Engineering, Waste water treatment, Non - Newtonian flow etc. At present he is working as an Associate Professor at Haldia Institute of Technology, Haldia, West Bengal.

Apurba Giri received the B. Tech., M. Tech. and Ph.D. degrees in Dairy Technology from West Bengal University of Animal and Fishery Sciences, West Bengal; Karnataka Veterinary Animal and Fishery Sciences University, Bangalore; and National Dairy Research Institute, Karnal, Haryana, respectively. During 2007-2009, he worked as a Sr. Officer in Banas Dairy, Palanpur, Gujarat. At present he is pursuing Post Doctoral Programme in an Indo-Denmark Project entitled as “High rate algal biomass production for food, feed, biochemicals and biofuels” at Agricultural and Food Engineering Department, IIT Kharagpur.

Prasanta Kumar Nandi received the B.Sc. degree from Burdwan University, West Bengal and both M.Sc. and Ph.D. degrees from IIT Kharagpur in Chemistry. His areas of research work are nonlinear optical properties of molecules (modeling & computation), Molecular electronic structure and spectroscopic properties, Chemical bonding etc. At present he is working as a Professor in Department of Chemistry, Bengal Engineering and Science University, Shibpur, Howrah.