ASSESSMENT OF DAIRY WASTEWATER TREATMENT AND ITS POTENTIAL FOR BIOGAS PRODUCTION AT TANGA FRESH LIMITED

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ABSTRACT

The extent of pollution of dairy wastewater treated in a septic tank and its potential for biogas production was investigated. Performance of the existing treatment system was assessed through characterization of both raw and treated effluents. From the analysis parameters like Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_{5}), Total Suspended Solids (TSS), alkalinity, turbidity, color and phosphorus disclosed inadequate system performance with treated effluent displaying higher values of organic matter than the allowed discharge limits according to the national standards. Optimal conditions for biogas production such as temperature, pH and type of inoculum were determined through batch experiments. The optimum conditions were 35 ^{o}C and pH 7.0 with cow dung as inoculum type, which resulted in production of 0.49 m^3 of biogas per Kg COD of dairy wastewater. The reduction efficiencies of COD, TS and VS were 98%, 78% and 73%, respectively. Therefore, these conditions can be applied for treatment of wastewater at Tanga fresh limited (TFL) Plant, to ensuring adequate dairy wastewater treatment and recovery of biogas while preventing environmental pollution from the 100 m^3 of dairy wastewater produced daily.

Keywords: Biogas; dairy wastewater characterization; environmental pollution; treatment conditions

INTRODUCTION

Industrialization is the cornerstone of development in any country. However, in most cases the industrialization process is accompanied with major environmental consequences worldwide (Braio and Granhem 2007). For instance, agroprocessing sector has the highest consumption of water while producing enormous amount of wastewater to the environment (Ramjeawon 2000). Dairy industry is one of the major producers of wastewater because water is the key processing aid (Sarkar et al.2006). Huge amount of water is applied in processing raw milk into products such as cheese, ice cream, butter, ghee and yoghourt by various processes, including pasteurization, coagulation, centrifugation and chilling (Kumar and Desai 2011). Furthermore strict observation of sanitation to maintain the quality of milk to satisfy customers' demand, in turn causes more variations in the wastewater generation in different factories (Shete and Shinkar 2013). Therefore, studies have been conducted with a view to address the menace caused by industrial wastewater pollution in order to safeguard the environment and the society at large (Kurniawan et al. 2006 and Shivsharan et al. 2013). Thus characterization of wastewater is the initial stage in dealing with wastewater as it is important for the estimation of pollution effects, the comparison of wastewater strength with standards given for discharge to the environment, and in deciding the type of treatment required for the wastewater (Renou et al. 2008).

In countries like Tanzania which are on the edge of fast tracking their industrialization process, proper industrial waste management systems are not in place and consequently although such undertaking may have positive impacts on the country's economy and on peoples livelihood, have eventual negative impacts on the environment through unregulated release of waste such as wastewater (Njau and Machunda 2014). Tanga Fresh Limited (TFL) is one of the milk processing factories in Tanzania; faced with challenges of adequately treating its wastewater. TFL wastewater is loaded with organic material coming from various places within the milk processing plant including the process room, receiving station, car wash, crate washer, flow washing and cleanliness; and from kitchen (ENVICON 2009). It releases 100 m^3/day of wastewater, which has been treated in a septic tank installed on the factory grounds followed by wastewater ponds constructed at a site owned by Tanga Airport Authority.

The septic tank was designed to treat about 22.5 m^3 of dairy wastewater produced per day. This means that the treatment unit is highly overloaded for the current wastewater flow rate of 100 m^3/day (Samwel et al. 2012). Therefore, this study focused on the assessment of the extent of pollution caused by the TFL factory effluent and conditions that would favor biogas production from the produced effluent. The findings of this study would be useful to TFL and other milk processing plants in planning for proper disposal, recycling and or utilization of wastewater (e.g. through energy generation and irrigation).

MATERIAL AND METHODS

Sample Collection

Grab wastewater samples were collected in a two liter air tight sampling bottles over 24 hours. The samples were collected from four different sampling points (SP) (Fig. 1) namely Inlet of the septic tank (SP-1), Outlet from the septic tank (SP-2), mixing point of the effluent from the septic tank, car wash and the kitchen wastewater (SP-3), and lastly the point within the wastewater ponds (SP-4). The samples were pre-treated with sulphuric acid to lower the pH to below 2.0 to prevent microbial activities (APHA 1998), thereafter they were transported in a cool box to the Nelson Mandela African Institution of Science and Technology (NM-AIST) laboratory ready for analysis.

Analytical methods

The dairy wastewater was analyzed in duplicates in the NM-AIST laboratory for Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_{5}), Total Solids (TS), Volatile Solids (VS), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Cl^-, SO_4^{2-}, PO_4^{3-}, NO_2^-, NO_3^-, NH_3, color, turbidity, and total alkalinity; Banana Investment limited (BIL) for VFA and Government chemist laboratory agency (GCLA) for C:N ratio and fat. Parameters like pH, temperature, dissolved oxygen, electrical conductivity and total dissolved solids were analyzed on site by using multiparameter instrument (HANNAH Model HI 9829). Laboratory analytical parameters such as; organic carbon, total solids and total suspended solids were analyzed gravimetrically at temperature ranging from103 to105°C then ignited at 150^{o}C for organic carbon and 550°C for volatile solid, while chloride and alkalinity were determined through titration method (APHA 1998 and Schumacher 2002), turbidity was measured using a turbidity meter while color was measured using (HACH -DR 2800 Spectrophotometer).

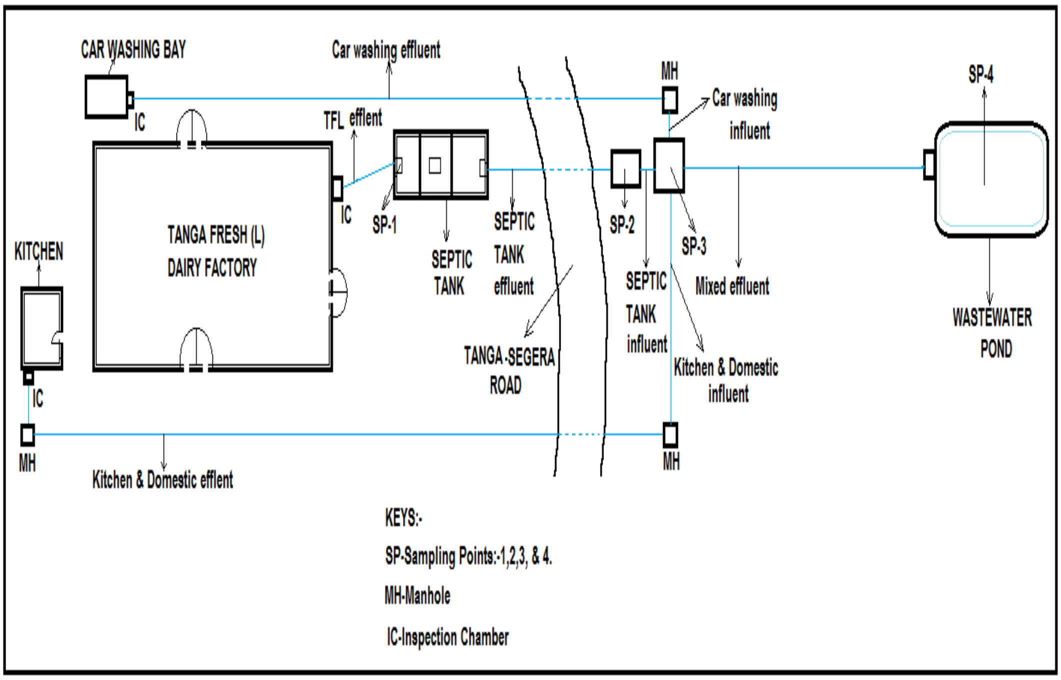

Figure 1: A schematic diagram for TFL layout and location of sampling points

Chemical oxygen demand (COD) was analyzed using a digestion method using HANNA model HI 839800 hot plates and measured by using COD and multiparameter photometer HI 83099 at 610 nm, Biological oxygen demand (BOD_5) was analyzed at 20^oC using Oxitop IS 12 BOD_5 incubators. Ammonia, ammonium and ammonia-nitrogen were determined by using Nessler's method, using DR 2800 spectrophotometer (HACH). Nitrate was determined by cadmium reduction method at 355nm, nitrite was determined by the ferrous sulphate method at 515nm, and phosphate was determined using Ascorbic acid method at 510nm using DR 2800 spectrophotometer HACH and Sulphate was determined using HANNA model HI 83099. Fat was determined by liquid-liquid extraction method while nitrogen was determined by TKN method where digestion using copper sulphate and sulphuric acid as a catalyst at 400^oC was carried out followed by distillation with boric acid as an indicator (Kirk and Sawyer 1991). Eventually, biogas composition to determine the amount of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S) and ammonia (NH_3) were analyzed by using biogas analyzer (BIOGAS 5000).

Experimental design and set up

Batch digesters were set using the side arm conical flask (Pyrex) of 1L capacity, water bath, measuring cylinder, beehive shelf, gas pipe and the water basin as shown in Figure 2. About 900 ml of the substrate was prepared for each setup in all experiments. The working volume for the reactors was 800 mL containing 80% dairy wastewater and 20% inoculum. Biogas was collected by water displacement method using an inverted measuring cylinder on a water basin, containing acidified brine solution which was prepared as described in (Iyagba et al. 2009). From the prepared mixture, 100 ml were stored in a refrigerator at 4°C for analyzing volatile solids (VS), chemical oxygen demand (COD), and total solids (TS). However, in each experiment different conditions were investigated at a time. These conditions set for experiments were such as mesophilic temperatures (25, 30, 35, and 40°C) because in mesophilic conditions bacteria can tolerate temperature fluctuations without affecting methane production (Weiland 2006), and pH (6.5, 7.0, 7.5, 8.0, and 8.5) (Sorathia et al. 2012). The effect of inoculum was also tested together with substrate from TFL factory dairy wastewater.

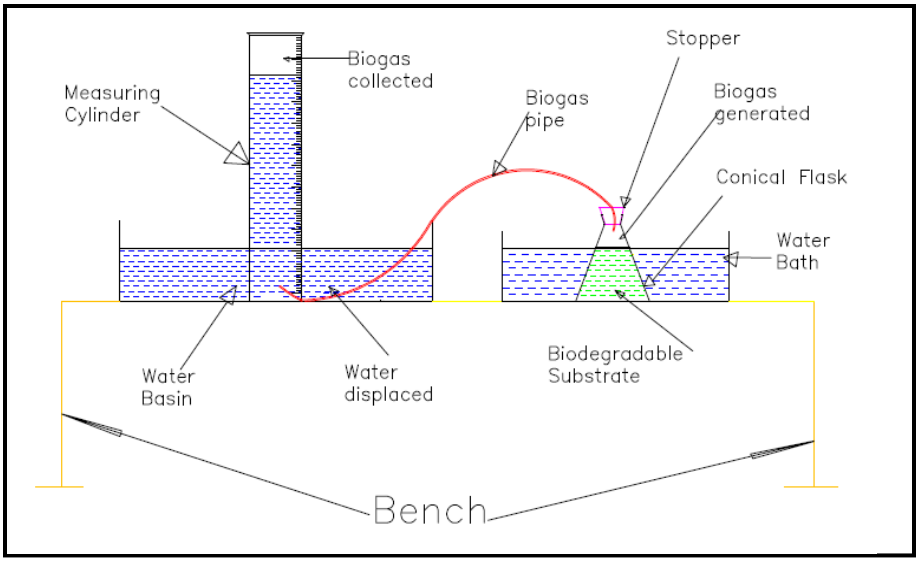

Figure 2: The set up of dairy wastewater biogas reactor

Optimization of temperature

In this experiment, four reactors containing 640 mL of dairy wastewater each were injected with 160 mL inoculum and were set in duplicates. Reactors A, B, C, and D contained dairy wastewater with inoculum were set at temperatures 25, 30, 35, and 40°C, respectively. The experiment was run for 35 days and after analyzing biogas composition, the effluent was taken for evaluation of pollutant reduction. The temperature was monitored using a thermostatic water bath system. The pH was measured to ensure the pH was within the recommended values, in this case 7.0 and regulation was done by 95% concentrated H_2SO_4. COD, TS and VS of the influent and effluent were monitored before and after each experiment. An inverted measuring cylinder containing acidified brine solution was used, supported with a beehive shelf for uplifting the measuring cylinder to allow the gas pipe (50 cm long and 10 mm in diameter) from the reactor for biogas collection. The experiment was set using separate water baths where each had a different temperature while all other conditions were kept constant. Biogas produced was recorded daily by reading the change in volume of acidified brine solution displaced by biogas in the measuring cylinder. The difference in volume of brine solution displaced was equivalent to the amount of biogas produced. The purpose of using acidified brine solution was to prevent the diffusion of gas in water.

Effect of pH

Four experiments were set at different pH, which was regulated by using 0.5 N NaOH and 1 M HCL. Hence, four reactors labeled A, B, C, and D were set in duplicate. Each of these reactors contained 640 mL of dairy wastewater and inoculum 160 mL as seeding material. The experiments were performed at pH 6.5, 7.5 8.0 and 8.5 while keeping all other conditions constant. The required pH was regulated by using sodium hydroxide and sulphuric acid. Daily recording of biogas was performed using the displacement method and acidified brine solution. The experiment was performed while biogas generation was recorded daily. The amount of biogas produced from different reactors was compared, and pollutants removal was evaluated to find the optimal pH for the treatment of TFL factory wastewater.

Effect of Inoculum type

In this experiment, two different inoculums were compared to find out the most suitable inoculum to serve as a seeding material in treating the TFL dairy wastewater. The inoculum compared were taken from banana wine effluent treatment plant and cow slurry manure which was taken from a domestic biogas system using cow manure, as a raw material for biogas production. They were added and treated on the same condition, and the efficacy was evaluated on biogas production and COD, TS and VS removal.

RESULTS AND DISCUSSION

The quality of dairy wastewater collected from TFL was bad even after treatment. Generally from the findings, the treated effluent had a bad smell and the milk color appeared in the treated effluent. The values of BOD_5 and COD were high in the treated effluents indicating high concentration of organic matter (**Table 1**). From the batch experimental study the optimum conditions indicated high pollution removal and biogas production at temperature 35°C and pH of 7.0.

Table 1: Characteristics of raw and treated dairy wastewater

Parameters	Raw effluent	Treated effluent	Units	Limit value	Standards
A: Biochemichal parameters					
COD	1945	903	mg/L	60	TBS
BOD_5 at 20°C	975	565	mg/L	30	TBS
TS	1275	1150	mg/L	n.m	
TSS	250	775	mg/L	100	TBS
Alkalinity	480	776	ppm	80 - 200	WHO
VS	300	550	mg/L	n.m	
VSS	50	125	mg/L	n.m	
DVS	250	425	mg/L	n.m	
VFA	-0.85	-1.65	mg/L	n.m	
SO_4^{2-}	19	0	mg/L	500	TBS
NO_3^-N	2.5	0.115	mg/L	20	TBS
NO_2^-N	0.618	0.33	mg/L	n.m	
NH_3^-N	4.775	7.56	mg/L	n.m	
NH_3	5.725	9.33	mg/L	n.m	

NH_4^+	6.4	9.78	mg/L	n.m	
PO_4^{3-}	10.85	6.45	mg/L	5	WHO
P^-	3.25	9.47	mg/L	n.m	
P_2O_5	7.25	14.59	mg/L	n.m	
Cl^-	134.02	174.07	mg/L	200	TBS
C:N ratio	5:1	29:1		n.m	
FAT	810	0	mg/L	10	TBS
B: Pysical parameters					
E.C.	670	839	µS/cm	1,000	WHO
Turbidity	302	191	NTU	300	TBS
COLOR	5410	3330	PtCo	300	TBS
Temperature	30	26.6	^oC	20 - 35	TBS
pH	7.03	7.075		6.5 – 8.5	TBS
DO	0.675	0.65	mg/L	n.m	
TDS	1050	375	mg/L	500	WHO

The efficacy of the treatment system

The performance of the system was assessed based on the wastewater parameters as per analysis of both untreated and treated dairy wastewater obtained from four sampling points (**Fig.1**) along the treatment system. The study revealed that the current treatment system was not performing well as it was indicated by color, COD, BOD_5, TSS and TDS and other parameters in the following descriptions although temperature and pH of the untreated effluent were within the allowable discharge limits.

Electrical conductivity (E.C) values in this study ranged from 670 – 960 µS/cm. The E.C values in the effluent are a representative of high concentration of solids and salts produced from milk processing plant (Atekwan et al. 2004, Sooknah and Wilkie 2004). Due to its accumulation in the septic tank even the effluent becomes high in the electrical conductivity. These values are within the range recommended by WHO for effluent discharge to the environment which is 1000 mg/L (Tiseer et al. 2008) making the treatment system suitable for this parameter.

Turbidity values varied from 117 to 302 NTU where the highest value of turbidity was observed at point 1 and 3. The reason for such observation at point 1 could be caused by large amount of organic matters before mineralization in anaerobic reactor to inorganic compounds (ions) and suspended solids (Wang et al. 2006b). The contribution of high turbidity at point 3 could be due to the mixing of wastewater from different streams including point 2 effluents, as well as the kitchen wastewater and car wash wastewater which is not treated. At point 4, the turbidity value dropped by 109 NTU from point 3 because the wastewater pond contains vegetations that enhance the filtration of suspended solids and organic matter decomposition when flowing through the system (Ran et al. 2004).

Another parameter was Dissolved Oxygen, which its values varied from 0.65–1.07 ppm where by the lower value indicated high concentration of organic matter that caused depletion of oxygen in the wastewater (Wetzel and Limnology 2001). However, (Pawar and Kolhe 2011) reported that, the maximum solubility of oxygen in water at 1 atm pressure ranges from about 15 mg/L at 0°C to 8 mg/L at 30°C indicating that DO in wastewater is not influenced by temperature but the concentration of organic matter and biochemical reaction.

The alkalinity values from this investigation ranged from 480 to 546 mg/L. Although the variation was not big for the three points the highest value was caused by sanitizers from the car wash and the kitchen and those used in cleaning the factory (Demirel et al. 2005). The obtained values were beyond the discharge limits. Therefore, this parameter needs to be careful treated because when the wastewater is released to water bodies may interfere alkalinity such that low alkalinity (below 80 mg/L) may corrode water pipes while high alkalinity (beyond 200 mg/L) make the water to buffer (Spellman 2013).

Chloride and Sulphate ranged from 58 to 174.07 mg/L and 0 to 22.5 mg/L, respectively. Based on these observations, point 3 and 4 are showing tremendous increases in chloride which can be explained by the inflow of salts coming from the kitchen and the car wash areas (**Fig.1**). Regardless of the fact that these points had higher values they still differed which may have been caused by runoffs during rainy season, and because of accumulation since point 4 is the endpoint of the treatment system with no outlet The lower value of sulphate at point 4 could be attributed to consumption of sulphate by sulphate consuming-bacteria in anaerobic digestion at the wastewater ponds (Wang et al. 2006a). However, according to Tanzania Bureau of Standards (TBS) chloride and sulphate values were within the discharge limits of 200 mg/L and 500 mg/L.

The values of C:N ratio observed in this study ranged from 5:1, 12:1, 14:1 and 29:1 at SP 1, 2, 3 and 4 respectively (Fig.1). Based on these results the C:N ratios determined were increasing from SP 1 to SP 4. The cause of low C:N ratio could be due to the fact that the bacteria has high demand for organic carbon for growth and respiration (Miller 2000). This resulted to poor degradation of organic matter as it is a receiving and mixing point of the wastewater from all processes taking place. However, the increase observed along the system was due to exposure of the wastewater to air that allowed nitrification in the presence of nitrifiers to perform the conversion of ammonia to nitrate. In this process carbon dioxide was used as a carbon source for the bacteria and was metabolized to organic carbon (Davis 2005, Watkins and Nash 2010). Furthermore, the tremendous increase at point 4 showed that there was an increase in carbon content from the wastewater coming from the kitchen and wastewater ponds vegetation. This in turn enabled the increase in the number of microbes, which also increased nitrogen consumption in the form of nitrate by vegetations (Kushwaha et al. 2011). Therefore, because the recommended ratio for effective and efficient treatment of wastewater is C:N ratio of 20-30:1, then co digestion would be important for TFL dairy wastewater treatment in future to obtain reliable amount of methane.

The determined values of solids from this investigation ranged from 1000 to 1075, 105 to 750, 375 to 1050, 50 to 550, 0 to 125 and 50 to 425 mg/l Fig. 11, for total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), volatile solids (VS), volatile suspended solids (VSS) and dissolved volatile solids (DVS) respectively. Higher values were due to organic matter accumulation (Tikariha and Sahu 2014). However, solid content in wastewater varies greatly depending on the process generating it although they are mostly influenced by environmental factors and salt concentration (Noorjahan et al. 2004). Moreover, solids carry a significant portion of organic matter that can highly contribute to the organic load of the wastewater and this can raise BOD to 60% in wastewater thus resulting to oxygen depletion (Pawar and Kolhe 2011). However, the TBS discharge limit for

suspended solids was 100 mg/L thus making the TFL wastewater inadequately treated.
Fat content ranged from 00 to 810 mg/L in this study with highest value being observed at point 1 (**Fig.1**) which may be due to the accumulation of fat because it was less degraded by microorganisms (Mobarak-Qamsari et al.2012). The point is also a receiving and mixing point of the effluents from all processes occurring in the factory. These could be the causes of all the fat to float on top of water and thus a clear separation that then allows only the water to move while leaving the fat behind. Higher values on the untreated effluents were also reported by other studies up to about 600 mg/L (Demirel et al. 2005, Pawar and Kolhe 2011 and Tikariha and Sahu 2014). The other points 2, 3, and 4 were found to have 0 values indicating that all the fat was left in the septic tank.

Volatile Fatty Acids (VFA) results were found to be negative in this study which indicated that acidogenesis process has not taken place in the treatment system to produce VFA (Wijekoon et al. 2011). The poor performance was because the system was overloaded, and the retention time was not enough for the wastewater to be utilized by microorganisms (ENVICON 2009) regardless of the fact that temperature and pH were favorable for microbial biodegradation.

BOD_5 values ranged from 530 to 975 mg/L in the four sampling (points 1, 2, 3, and 4) (Fig.1). The highest value of BOD_5 was observed at point 1 (975 mg/L) on the raw effluent. The value decreased abruptly to reach the lowest value at point 2 (530 mg/L). The BOD_5 was noted to increase at point 3 to reach 685 mg/L, which again dropped to 565 mg/L at point 4. The highest value of BOD_5 observed at point 1, might be due to accumulation of organic matter (Noorjahan et al. 2004). This can be supported by the observed low value of DO (0.67 mg/L) and increase of total solids to reach 1275 mg/L. However, the presence of high and low values of BOD_5 in this study still indicated high degree of pollution because they are beyond the discharge limit of (30 mg/L) given by TBS.

The COD values were observed to vary at all points whereby point 1 had a value of 1245 mg/L. There was a continued decrease of COD value of 935, 907.5 and 903 mg/L at points 2, 3, and 4 respectively (Fig.1). Based on these results, a high value was observed at point1, which signifies the accumulation of organic matter and chemical substances as raw effluent. despite the fact that conditions like low DO of 0.67 mg/L and pH of 7.0 were favorable for anaerobic digestion, microorganisms could not degrade or transform the fat or scum into simple substances because the system does not favor hydrolysis instead the scum/fat builds-up and increase the COD. At point 2, the COD decreased by 310 mg/L because most solids remained in sampling point 1 and the degradable organic matter was digested as proved by the decrease of BOD_5 by 445 mg/l. The marginal decrease observed at sampling point 3 and 4 is a sign that the car wash, kitchen streams and vegetation die-off in the wastewater ponds contained organic matters. However, the treated effluent was still concentrated with organic matter (Table 1) because the discharge limit given by TBS was 60 mg/l. Therefore, this indicated that the whole chain of dairy wastewater was not sufficiently treated indicating that the endpoint was highly concentrated with organic matter (Sarkar et al. 2006).

The values of nitrogen compounds were ranging from 0.115 to 32.5 mg/L for NO3 --N, 0.33 to 0.62 mg/L for NO^{2-}-N, 3.65 to 17.0 mg/L for NH3-N, 4.25 to 16 mg/L for NH4+-N, and 4.13 to 16 mg/L for NH3. For the case of phosphorous compounds, the range was from 9.47 to 16.0 mg/L for PO_4^{3-}, 3.25 to 6.4 mg/L for P- and 4.13 to 16.0

mg/L for P_2O_5. The lower values were observed for nitrite nitrogen because it is used as electron acceptor in anaerobic digestion for conversion of ammonium to nitrogen gas and nitrate (Yamamoto et al. 2006) through denitrification while nitrification may have caused an increase in nitrogen at air exposed points (Gottschall et al. 2007). The high concentration of nitrate can affect humans and livestock because it causes oxygen transport failure into body systems (Shete and Shinkar 2013).

The source of phosphorus is usually from the dairy wastewater and cleaning agent (Wang et al. 2006b). Higher values indicated less consumption by microbes, but the low values were because of chemical reactions that caused precipitation with calcium and magnesium coming with wastewater from the kitchen and car wash making phosphorus less soluble (Wetzel and Limnology 2001). The presence of nutrients in large concentration in water can cause excess weed and algae growth (Scheffer and Van Nes 2007). Untreated wastewater with a high level of nutrients can contaminate drinking water and cause damage to aquatic organisms because algae use up the oxygen present in the water, and can further cause clogging on filters (Demirel et al. 2005).

The result of this investigation revealed that, the Tanga Fresh Limited treatment system was not performing well. This was reflected in the higher values of COD (903 mg/L) and BOD (565 mg/L) in the effluent of the treatment system as main indicators of pollution in wastewater as their discharge limits are 60 mg/L and 30 mg/L for COD and BOD respectively. For the case of nitrate the value was very low (0.115 mg/L) while the discharge limit for nitrate is 20 mg/L, in addition phosphate had a value of 9.47 mg/L which seems to be high compared to the discharge limit given for total phosphate being 6 mg/L to mention few. Considering additional parameters like pH and temperature do not need adjustment because they are within the discharge limits. However, other parameters like turbidity is within the discharge limit while color is beyond the discharge limit (300 mg/L). Moreover, the system was found to be performing poorly because the capacity of the system was less compared to the amount of effluent produced daily (100 m^3/day while the capacity is 153 m^3) which does not allow a retention time of 4 days. Since the problem was discovered the study of a new treatment method was carried out which involved investigating the suitable conditions that could allow proper treatment and also the value of TFL dairy wastewater for biogas potential.

Biogas Generation and Quality

The ability of TFL dairy wastewater to produce biogas was investigated based on the volume of biogas produced, total solids (TS), and volatile solids (VS) reduction as well as COD removal efficiency in all experimental setups.

Effect of Inoculum type

Take into account the results in figure 3; there was high biogas production from the application of cow slurry as a seeding material for treating dairy wastewater compared to the use of banana slurry. The reason was probably because the cow slurry could easily acclimatize and adapt to the presence of dairy wastewater because the two are from the same source (cow). For the case of banana slurry as the figure shows the biogas produced was very little, and the reason could be that, the methanogens of the inoculum were already adapted to the banana waste as a raw material, thus changing the raw material made it difficult for the bacteria to cope (Forster-Carneiro et al. 2007 and Ward et al. 2008). In this case, there was more adaptation with the cow slurry than the banana slurry although if time was given for the banana slurry to acclimatize maybe it would have performed well.

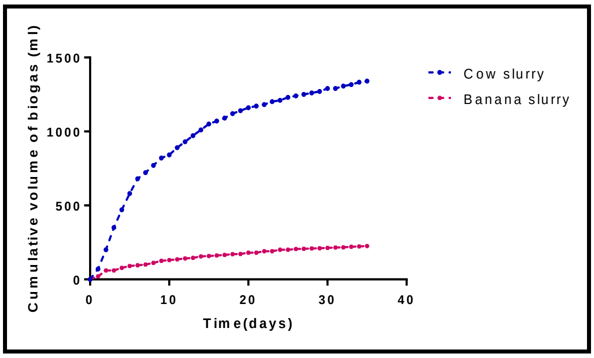

Figure 3: Biogas generated from two different inoculums

Effect of pH

From the five substrates, the one with low pH had lower biogas production, and it was expected that the drop in pH inhibits methanogenic bacteria causing a drop in hydrogen partial pressure hence accumulation of organic acids (Valdez-Vazquez and Poggi-Varaldo 2009). Maximum biogas production was recorded at pH 7.0 to 7.5 with an optimum production at pH.7.0 (Fig.4). Other observations were on the increased pH which resulted to reduced biogas production at pH higher than 7.5 which can be attributed to the sensitivity of methanogens to pH increases. Usually, pH is the function of volatile acids, bicarbonate, alkalinity of the system and carbon dioxide. Therefore, in order to have a constant pH it is crucial to adjust the relationship between bicarbonate and volatile fatty acids (Liu et al. 2009) because they can highly affect pH. It was also noted that pH varied with the different stages of wastewater treatment the anaerobic process due to difference in the levels of microbial activities.

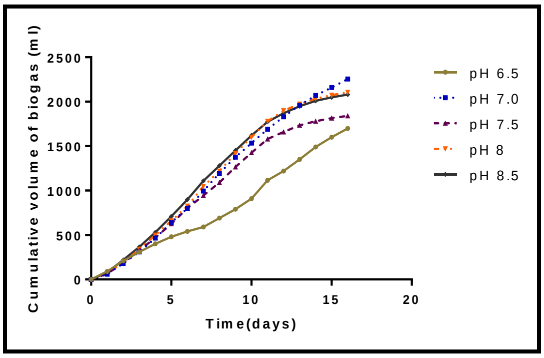

Figure 4: Cumulative biogas produced at different pH levels

Effect of Temperature

The role of temperature in influencing biogas production was investigated in various ranges starting from 25, 30, 35, and 40°C while keeping other factors constant in order to know at which temperature the substrate produces more biogas. According to the results the highest biogas production was obtained at Temperature 35°C and the lowest production of biogas was at temperature 25°C. At 40°C the production of biogas was low compared to 35°C but a short time was used for degradation of the organic matter (Fig.5). The mesophilic temperature is usually recommended since a number of microbial consortia can tolerate greater changes in the environment and is easier and stable to maintain (Arsova et al. 2008).

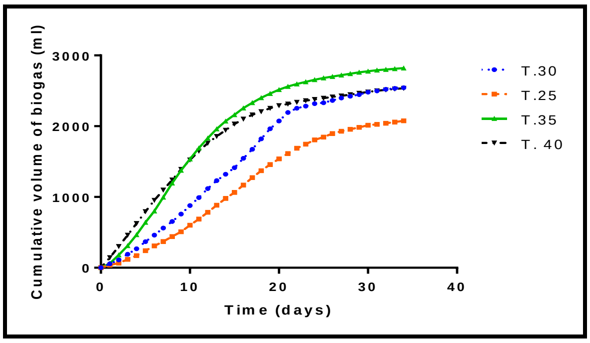

Figure 5: Cumulative biogas produced at different temperatures

Gas Composition

The biogas produced from the anaerobic treatment system is usually composed of different gases, including methane as the targeted gas, carbon dioxide, hydrogen sulfide, ammonia and oxygen. From this investigation, the biogas was analyzed and the results are as shown in figure 6. From the results, it indicated that methane had a composition of 67%, carbon dioxide of 28%, and hydrogen sulfide of 5ppm, ammonia of 10ppm and oxygen of 5ppm. These results tell us that dairy wastewater can be a very useful source of energy as recommended by other researchers (Mohan et al. 2007 and Rao et al. 2010).

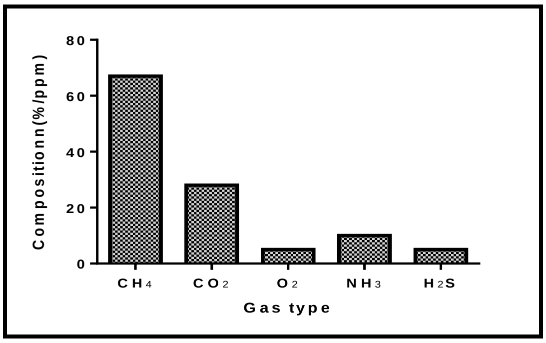

Figure 6: Gas composition of TFL dairy wastewater

CONCLUSION

It is clear from this study that the TFL wastewater treatment system is overloaded and is releasing polluted water to the environment. The increase in production of dairy wastewater from 22.5 m^3 to 100 m^3 that overloaded the wastewater treatment system is the contributing factor. In addition, the low C:N ratio (5:1) may have resulted in high concentration of ammonia that may have inhibited the bacteria from adequately degrading the wastewater (Miller 2000). Batch experiments have also confirmed the potential for biogas production from dairy wastewater at optimal temperature of 35 °C, pH 7.0 and cow dung slurry as inoculum type of choice. The biogas yield at these conditions was 0.49 m^3 /Kg COD. Removal efficiencies of COD, TS and VS at the optimal conditions were 98%, 78% and 73%, respectively and the composition of methane was between 60–70%. Also further studies on Codigestion would be inevitable for effective treatment of TFLwastewater.

ACKNOWLEDGEMENT
The authors are thankful to the Government of Tanzania through NM-AIST for funding this study and the TFL management for their full cooperation, support and facilitating wastewater sampling during the time of this study. Many thanks also go to Mr. Paschal Chrisogoni, Dr. Jackson Mwaigonela and Dr. Anselm Moshi for their assistance in writing this work.

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