Quantitative and qualitative variations of effective parameters on biogas produced from mixed wastes in anaerobic digester: Bench scale

Abdoliman Amouei (iamouei1966@gmail.com)
Babol University of Medical Science https://orcid.org/0000-0002-2873-2532
Ali Darvish Sasi
Mazandaran University of Science and Technology
Aliakbar Amooey
Mazandaran University of Science and Technology

Research Article

Keywords: Catering wastes, Anaerobic digestion, Bench scale continous reactor, Biogas

Posted Date: June 28th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-662591/v1

Abstract

Today, biogas production from municipal solid waste as one of the most important sources of energy supply in the world is increasing. In this study, the potential of biogas production from a mixture of cow dung and catering waste was investigated using a continuous flow anaerobic bioreactor with 60 litres at the Bench scale. Operational parameters such as pH, Carbon to Nitrogen ratio (C/N), mixing ratio of restaurant and cow waste in weight percentage (0:100, 50:50, 70:30, and 100:0), total solids (TS) (%5, %10 and %20), temperatures (35, 45 and 55°C) and oxidation-reduction potential (ORP) were evaluated. The results showed that the maximum yield and percent of the biogas produced from cow manure digestion separately was 1003 ml/day and %52.82. Digestion of the catering waste and cow manure as a mixture showed the best mixing ratio, total solid and temperature is 70:30 (w/w), %20 and 55°^{C} respectively and biogas production yield and percent in this conditions was obtained 5430 ml/day and %74.4 respectively. The ORP obtained in this study is -327 millivolt (mv), which indicates the appropriate conditions of the anaerobic process in biogas production and confirmation of methanogenesis.

Introduction

Each year, approximately 33% of the total food consumed by humans in the world is wasted, which according to the Food and Agriculture Organization of the United Nations report is 35.1 billion tons. On the other hand, the amount of disposed food waste in American restaurants and supermarkets is estimated at about 30 billion a year [1].

Catering waste is any waste produced in kitchens, canteens and restaurants [2]. These wastes are generated not only at household level but also through catering services, which accounts for about 30% of the total food served [3]. Catering waste consists mainly of fruit, meat, vegetable waste and animal by-products, which are not only rich in proteins, carbohydrates, fats and lipids, but also contain a variety of vitamins and other nutrients [4, 5].

The most appropriate way to manage this waste is to reuse it for the poor. But this method requires some measures such as separation and sanitary recycling on site before turning into waste, as well as their transportation and delivery to the poor, which is not economically and also due to the fast degradability of this waste by microorganisms is not healthy. Other methods of treatment and disposal of this type of waste include composting, incineration, landfilling and anaerobic digestion (AD). The composting method requires a large area of land and also creates an unpleasant odor [6]. Waste incineration is an expensive method and causes health and environmental problems such as the release of toxic chlorinated compounds and dioxins into the atmosphere [7, 8]. Landfilling also needs enough land and destroys usable foods and contaminates groundwater resources [9, 10].

Anaerobic digestion (AD), as a biological process that is used to degrade of organic compounds by microorganisms in absent of oxygen. The process has many advantages, including the production of the useful various intermediate organic compounds, the generation of energy in the form of biogas, the production of organic fertilizer, and is a safe method to deal with environmental problems such as water and air pollutions. The organic pollutants can be degraded through the metabolism of anaerobic microorganisms to decrease environmental pollution [7,9]

And up to now, the AD technology has been widely applied in many countries for waste treatment [10]. In addition, the produced biogas can be applied as clean renewable energy, and slurry of this process containing abundant nutrients including nitrogen, phosphorus and potassium, has great potential for liquid fertilizer preparation [11].

Wang et al.s studied on the effect of total solids on the anaerobic digestion process of a mixture of pig waste and food waste. The results showed that increasing the total solids from 5 to 15% had no effect on the amount of methane produced, while with TS of 20% the amount decreased [8]. In the study of Malik et al., A mixture of food waste and caw dung was used to produce methane gas by anaerobic process. This study showed that in the ratio of 1:1 food waste to cow dung and 2.5 kg VS/m, the amount of biogas produced was 1620 liters per day [1]. In the study of Al-Mashhadi and Zang, in the field of biogas production from a mixture of dairy waste and food, the amount of biogas production by the anaerobic digester in mesophilic conditions was investigated. In this study, the average amount of methane produced from fine and coarse mixed wastes within 30 days was 302 and 228 liters per kilogram of escape solid, respectively, and the percentage of biogas produced in these two cases was 93 and 87 percent, respectively [6]. In the study of Patti et al., Digestion of food waste using caw dung was performed by anaerobic process. The results of this study showed that the amount of biogas production was influenced by parameters such as pH, temperature and water to solid ratio so that in the ratio of solid to water 1: 2 and neutral pH, the amount of biogas production was maximum. Also with increasing temperature 25 At 40 ° C, the production of biogas decreased from 110 to 142 ml and at higher temperatures this amount decreased [7].

In this study, effect of the operational parameters such as pH, temperature, TS, C/N, and ORP index in biogas production from a mixture of cow dung and restaurant food waste was evaluated using a continuous flow anaerobic bioreactor and then the best process conditions according to the tests performed was assessed.

Materials And Methods

2.1. Description process

The first step, the used materials was completely crushed and particle size less than 3 mm by extruder with speed of 1000 rpm and then the materials are mixed with water by mixer with given volume 10 liters.

The second step, the prepared materials was transfer into the homogenizer tank with operational volume 80 liters. During the homogenization process, the physical and chemical properties of the materials were measured according to the experiment.

The third step, the materials was pumped through the homogenizer tank into the digester. The digester was made of stainless steel with operational volume 60 liters and temperature of inside was adjusted by the thermal coil. There was a tube in the gas outlet of the digester where the produced gas was stored and sampled. In figure (1) schematic of this process was showed.

2.2. Materials

Caw dung was collected from the cattle bed in one of livestock in Iran and catering waste collected from university of Mazandaran restaurant. The constituents of food waste are shown in Table 1.

Food waste constituents in this studyTable 1.

Materials	Weight (kg)
Rotten eggplant and cucumber	2.6
Cooked rice	7
Chicken skin and non-consumable chicken	4
Rotten and unusable tomatoes	3.4

The constituents reported in Table (1) were constant throughout the experiments. All of these substances are mixed together in all experiments. Table (2) show the physical and chemical properties of food waste and cow dung.

Table 2: The physical and chemical properties of food waste and cow dung

Value	Food waste	Cow dung
TS (%)	2	0.9
C/N	37.8	67.5
Volatile solids (%)	0.74	0.13
pH	5.9	6.3
(g/ml)	1.05	1.05
Fe (ppm)	350	2375
Mg (ppm)	15	4.5
Ca (ppm)	16.1	47.1
P (ppm)	0.04	0.66
Cd (ppm)	3.1	0.1
Pb (ppm)	0	0.018
Cr (ppm)	7.15	0
Ni (ppm)	5	0
Total Nitrogen (%)	1.06	1.62

Research method (Methodology) 2.3.

- In the first step, digestion of food waste and cow dung at constant density separately were performed and finally, the biogas production potential and methane concentration was measured. Secondly, digestion of food waste and cow dung at constant density with different weight ratios (50:50 and 70:30 respectively cow dung and food waste) were done and measure of the biogas production potential and methane concentration were performed. In the third step, the best percent composition based on biogas production potential and methane concentration was selected. After selecting the best percent composition, the best total solids at values of 5%, 10% and 20% were determined. In the fourth step, after selecting the best total solids in the best percent composition, the appropriate temperature (35, 45 and 55) conditions for biogas production and the appropriate gas concentration were studied. At all stages of the measurement of biogas production and methane concentration, the amounts of pH and ORP were determined.

2.4. Measurement

After biogas production, the gas was stored in the tube and the amount of gas produced every three days was measured using flow meter (MSA ALTAIR 4X). Total carbon and nitrogen, total solids, volatile solids and other elements such as Fe, Ca, Mg, Cd, Pb, Cr and Ni were measured by the standard methods [12-14]. The pH and ORP amounts of the process in all stages were measured by pH meter (MTT65 model) and ORP meter (BANTE Company, Scan 20 model).

Results And Discussion

3.1. Anaerobic digestion of food wastes and cow dung wastes

3.1.1. pH effect

Figure 2 shows the pH changes in the anaerobic digestion of food wastes and cow dung wastes.

As can be seen in Figure 2, the pH changes in the digestion of food waste of University of Mazandaran was slow and finally reached 5.3, which is not suitable for the growth of methanogenic bacteria [15]. Therefore, the concentration of methane during the catering waste digestion process was low. On the other hand, changes in the pH variable in the digestion of animal waste indicated that the accumulation of volatile fatty acids in the digestion of these substances was low, because the pH changes after 15 days, reached above 6.8, which indicates growth conditions were suitable for the bacteria and naturally the methane concentration was higher than the catering waste [16].

The optimum pH for methanogenic bacteria growth is 6.8 to 7.2 [17]. As you can see, by increasing the amount of cow waste to the catering waste, the time of hydrolysis and acidogenesis processes are reduced and after the 18th day onwards, the condition will be reached at pH=7 (stability condition).

3.1.2. ORP effect

As can be observed in Figure 3, the changes in ORP for catering waste individually was low during 24 days and this value was eventually reduced to -100 mV, indicating that the digestion process the ORP variations in the digestion of catering waste was slow. The catering waste ended up in the same part of acidogenesis alone and consequently the pH did not rise above 5.44 during the digestion process due to the lack of methanogenic bacteria growth and consequently the concentration of methane was decreased.

However, in the co- digestion of catering wastes and Cow dung in weight ratios of 50:50 and 70:30, the amount of ORP variable was -318 and -327 mV, respectively. Also, pH variations in the co- digestion of catering wastes and cow dung in weight ratios of 50:50 and 70:30 were increased by 7.2 and 7.3 on the 24th day, respectively, which indicates that in these two compounds prepared, a good proportion to the anaerobic process and methanogenic phase progress. The optimum of ORP and pH during the acidogenesis and methanogenesis phases were -284 ± 32.71 mV; 5.76 ± 0.24, and -335.63 ± 28.97 mV; 7.49 ± 0.24, respectively [18].

3.1. 3. TS effect

Most research has shown that TS content in wastes more than 20 % decreased methane production [8]. Some studies have shown that the decrease in methane production can be due to the reduction in mass transfer rate, which occurs due to the decrease in water content in high TS [6]. In this study, the mixture has been diluted with water to obtain the studied TS contents (TS 5%; TS 10%; TS 20%) and then fed into the digesters after fully mixing. As can be observed from figure 4, When TS of lignocellulose materials decreases from 20 to 5 %, the biogas production decreases (Fig.4a) but the amount of methane content in terms of percentage increases (Fig.4b). The reason of this can be related the mass transfer phenomenon. Mass described that is why in this study we considered the study range of biogas production between 5 to 20% [8]. According the results, the amount of biogas production and the methane content in TS 20% were the highest in 4125.6 ml and 73%, respectively.

3.1.4. Temperature effect

As the results reported in section 3.1.3, biogas production and methane content in TS 20% were the optimum condition. All previous results were reported at 35 . Regarding of the effect of temperature variations on the biogas production and methane content, so in addition 35 (mesophile), two temperatures of 45 and 55 (thermophile) were studied. As can be seen from the figure 5, the temperature changes in the biogas production and methane content was effective. The reason of this phenomena is associated to increasing the growth rate of microbial species of anaerobic digestion with increasing temperature [20].

According to Figure 5, with increasing temperature to 55 ° C, the amount of biogas production increased by 5200 ml, but the content of methane gas at 55 ° C grew faster than temperatures of 35 and 45 ° C and finally were stabilized in the range of 75% methane concentration. As the temperature changes in Figure 5 show, there was methane content stability at 35 °C, 45 and 55 °C, due to lack of substrates and food per microorganisms (F/M) ratio in the [21].

Conclusion

Finally, the results showed that for anaerobic digestion of self-service waste of University of Mazandaran in the best optimal conditions, the mixing rate of 70:30 should be 70% of animal waste and the amount of TS should be 20%. Also, for better operation and reduction of hydraulic time, the temperature should be set at 55 ° C to have the best performance for biogas production. Because at this temperature we saw the best performance in terms of methane gas concentration of 75% and biogas production of 5200 ml.

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Figures

Figure 1

Schematic diagram of the process: Extruder (1); Mixer (2); Pump (3); Homogenizer tank (4); digester

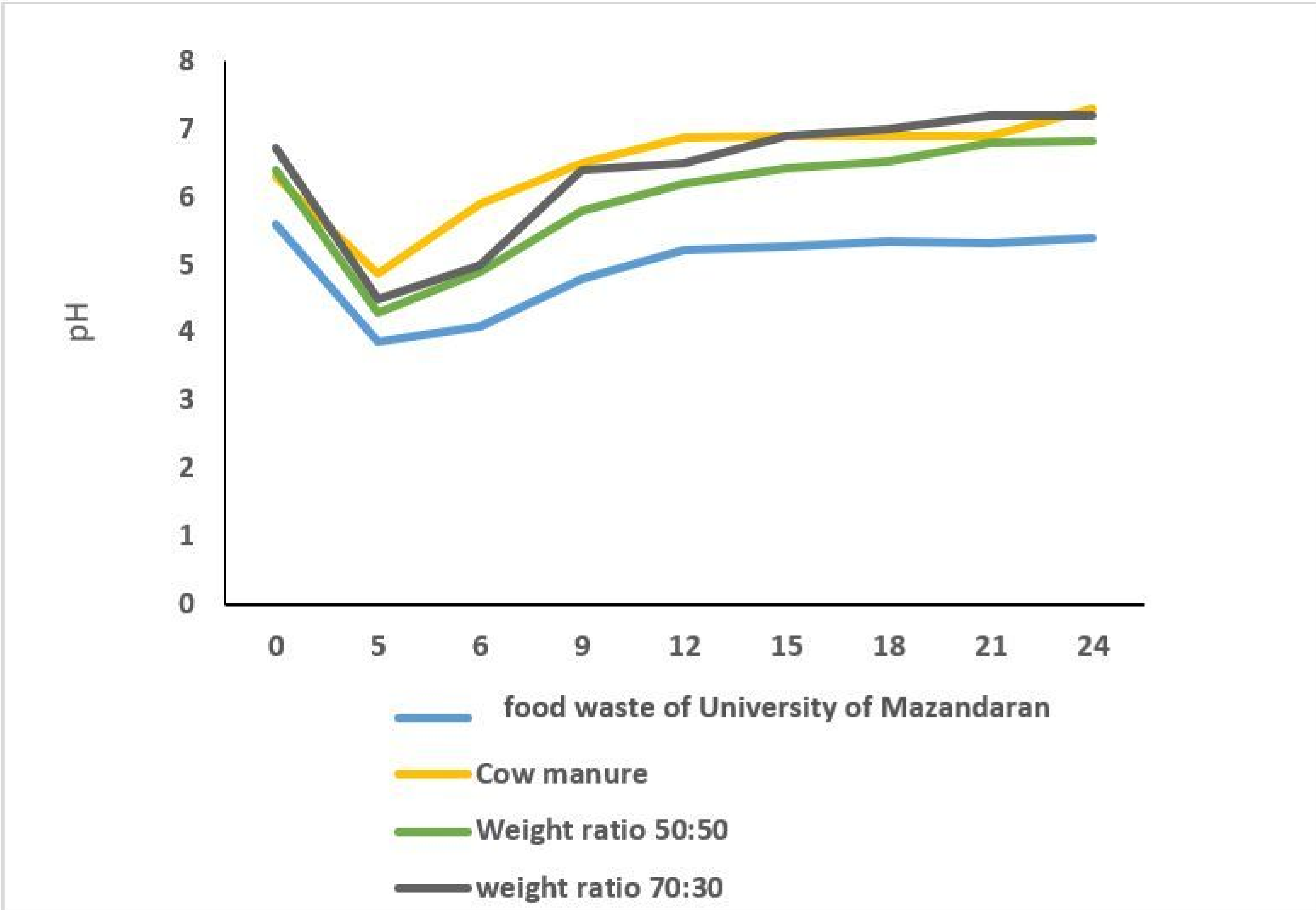

Figure 2

Changes in pH from anaerobic digestion of food wastes and cow dung wastes

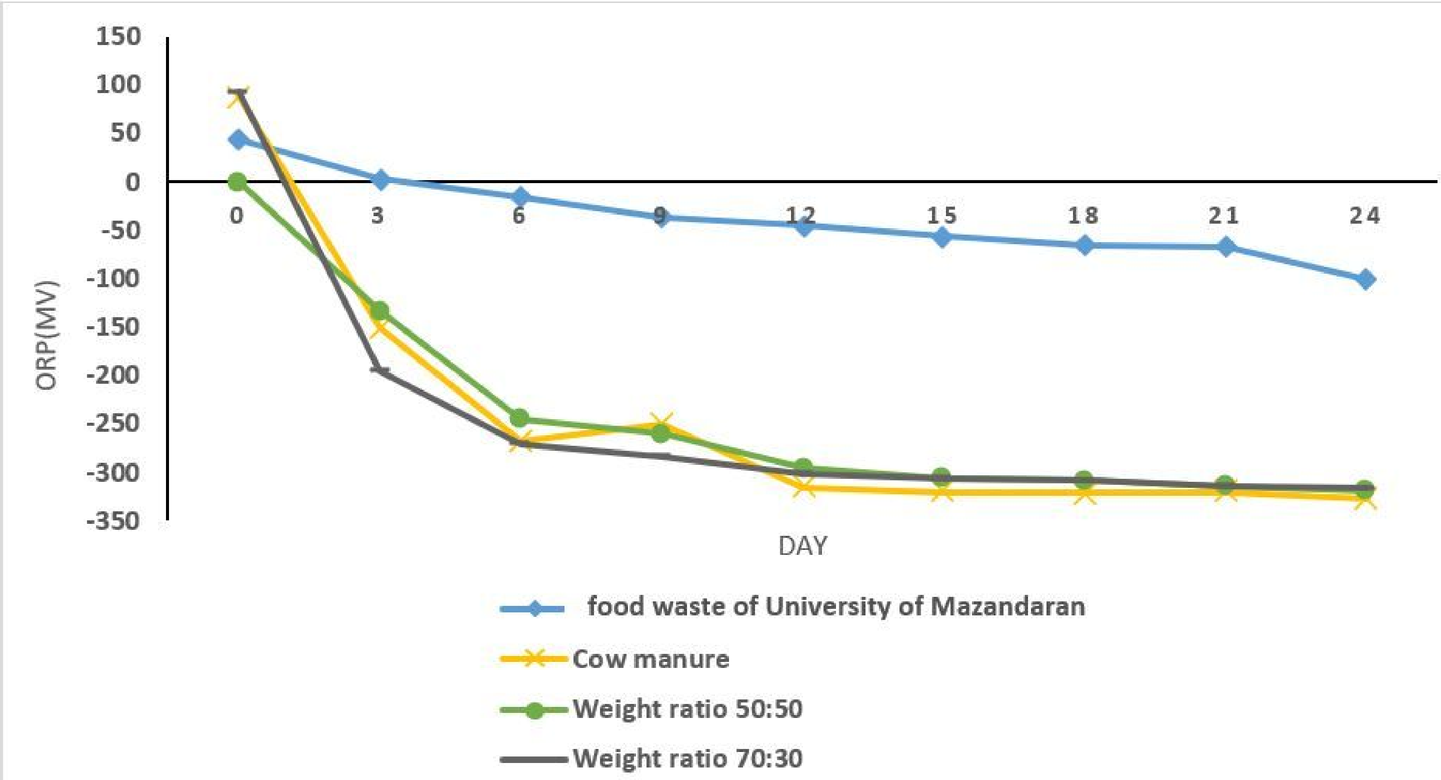

Figure 3

Changes of ORP in digestion of catering wastes, cow dung and co-digestion of these two wastes

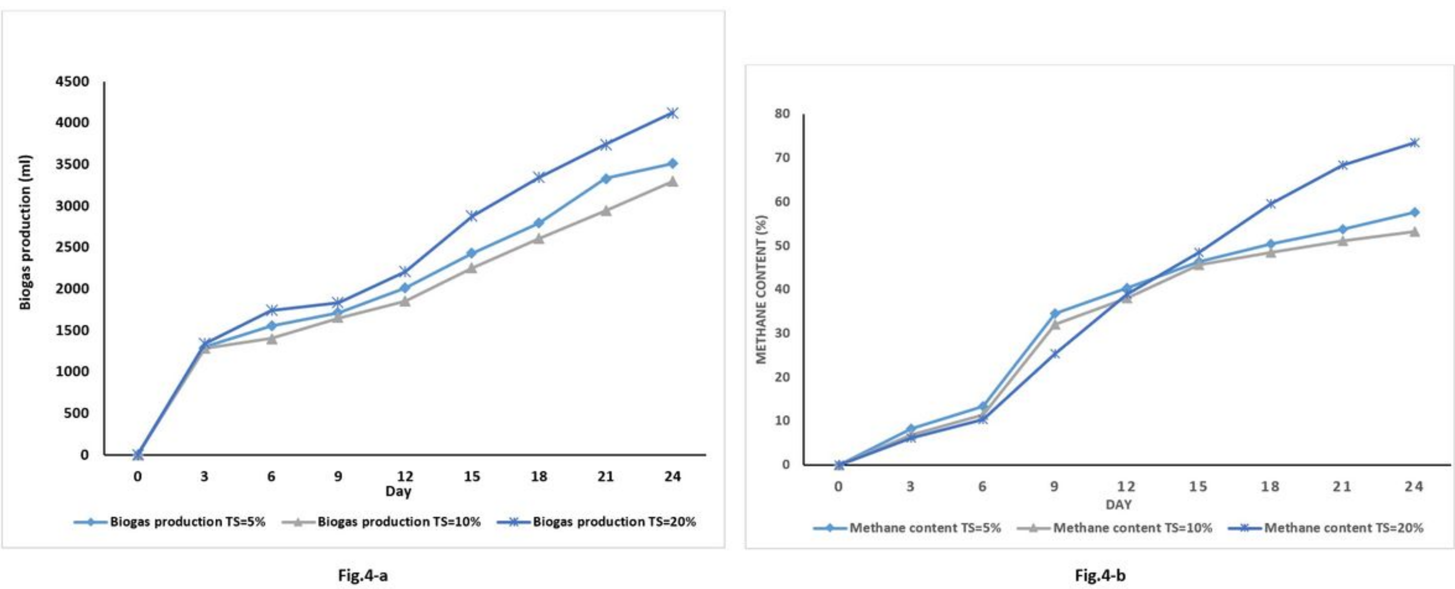

Figure 4

Biogas production (a) and methane content in different total solids

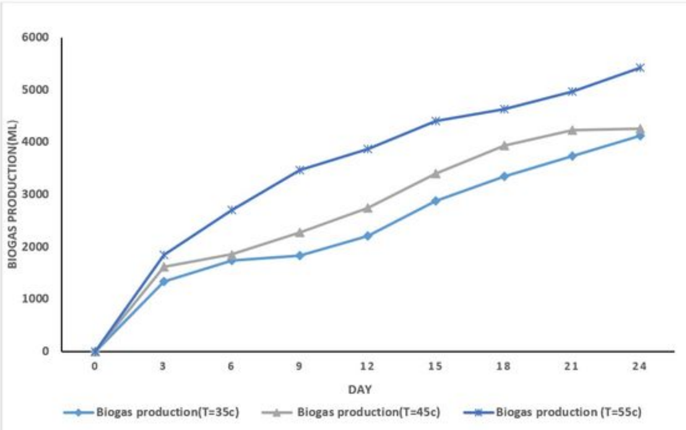

Fig.5-a

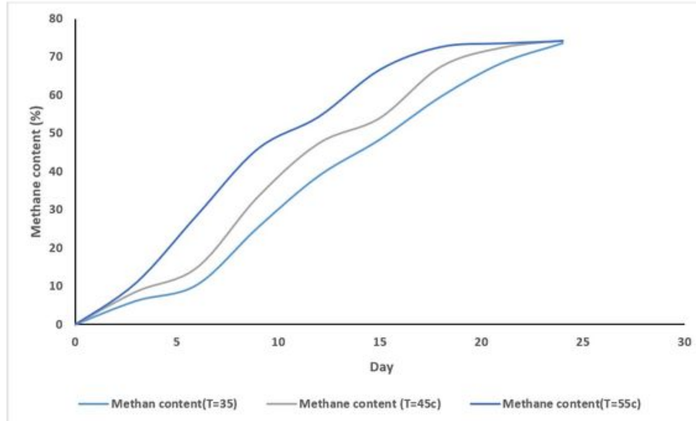

Fig.5-b

Figure 5

Biogas production (a) and methane content in different total solids