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Research Article

Optimization of conditions for Biomethane production through anaerobic digestion of domestic fruit waste

Summyia Khalid*, Muhammad Gulfraz and M. Sheeraz Ahmad

Department of Biochemistry and Biotechnology, PMAS Arid Agriculture University Rawalpindi, Pakistan

Abstract

An energy crisis is main issue of Pakistan and spending larger amount of foreign exchange for import of fuels. Main source of energy in Pakistan is fossil fuels but these sources are non renewable. Therefore to fulfill energy demand alternative energy sources like renewable source are best choice. The present study was conducted for biomethane production by using different concentration of fruit waste along animal manure at various pH (6-8.5) and temperature like (33-37°C) respectively using anaerobic digestion. Biochemical analysis of fruits waste was determined and results revealed that fruit waste is a best option for biofuel production. This study was conducted at mesophilic temperature range and 35°C is considered to be best temperature. PH range also effect the biomethane production and best production is at 8 pH. Retention time and concentration of manure and waste also effect the biomethane production. Biomethane production was also effected in presence of different heavy metals. Iron, magnesium, calcium, sodium and nickel were present about 7.1ppm, 12ppm, 2.6ppm, 7.8ppm and 1.9ppm respectively. Maximum Biomethane produced through this study was 15.25l/ kg/day at 35°C and pH 8. Biogas produced was filtered by mixing solution of calcium hydroxide. Biomethane production was confirmed through flame test. Flame produced was blue and violet in color. Biomethane produced used for cooking purpose. It is considered to be safe and economic method for energy production.
Keywords: Biomethane, anaerobic digestion, fruit waste, inoculum, mesophilic

1. Introduction

Energy is basic need of life, day by day energy demand is increasing. Although Pakistan has many sources of energy but energy consumption is more than energy production. Most of the energy requirement in Pakistan is fulfilled from fossil fuels. Fossil fuels are the sources which are non-renewable so once used these resources are not recovered. In Pakistan we need some substitute energy sources as Pakistan is facing energy shortage [1].

Landfill disposed of Food waste causes the problem of unpleasant smells and leachates of food waste if not handled in proper way polluting underground water. For treating food waste, anaerobic digestion is considered to be best. Over the few last years, food waste has been considered the most studied feedstock for biomethane production, especially kitchen waste [2].

Biofuel production mostly used Organic matter. According to nature of organic matter used for biofuel production it is divided in to four generations [3]. In First generation crops are used for biofuel production [4]. Second generation used woody parts of plants and organic waste including food waste for biofuel production [5]. Third generation used alga for biofuel production. In Fourth generation biomass material is used for biofuel production which used carbon dioxide during its growth [6].

Anaerobic digestion is process of biological degradation by complex microorganisms. For biomethane production, process of anaerobic digestion involved four steps. In first step, for conversion of polymers in to monomers cellular enzymes used. In second step, monomers of hydrolysis step further converted in to alcohols, hydrogen, organic acid and carbon dioxide in presence of acidogenic bacteria. In third step, product of acidogenic step converted in to simpler units by using acetogenic bacteria. In last step, methane gas is produced by using methanogenic bacteria including methanococcus, methanobacillus [7]. The waste produced during biomethane production used as fertilizer [8].

* Correspondence Info

Summyia Khalid
Department of Biochemistry and Biotechnology
Pmas arid agriculture university Rawalpindi, Pakistan
E-mail: Summiakhalid_31@yahoo.com

Two types of system used for anaerobic digestion, Batch and continuous. In continuous digesters, substrate added continuously and regularly. Every time biomethane produced new substrate added while in batch system substrate added and left until biomethane produced [9].

By using biological and chemical processes biomass of waste can be converted in to fuel. Ratio of waste and inoculum is also important for biomethane [10]. For inoculum preparation waste and manure is used in suitable ratio. Biomethane production and digester performance is affected by different parameters. Most important parameter which effect biomethane production is temperature and pH. Specific system used for nonstop biomethane production, specific control system maintains pH and temperature [11]. Biomethane production is also effected by amount of total solid. Number of days also affects biomethane production, according to weather conditions numbers of days vary. In cold weather, number of days increases for biomethane production [12].

Different microorganisms have different pH range. For good methane production pH range is from 6.5 to 8 with moisture contents of 90 to 96%. Some microorganisms like fermentative, work between 4 to 8.5 pH ranges. pH more than 8.3 and less than 6.1 decrease methane production[13]. Temperature is also important for biomethane production. Biomethane formation takes place in three different temperature ranges that is thermophilic, psychophilic and mesophilic. Mesophilic temperature range is from 32°C to 38°C. Methanogenic bacteria work best in this temperature range. Hilly areas where temperature decrease during winter decreases biomethane production because bacteria become inactive at temperature lower than optimal for their growth [14].

The time in which solids remain in digester is called solid retention time, whereas the time which liquid sludge spends in digester is called hydraulic retention time (HRT). Production of biomethane depends on retention time. Reaction time can be decreased by decreasing retention time. Every time sludge is removed a part of bacterial population also removed [15].

Metals present in substrate also effect biomethane production. Some metals increase biomethane production and some decrease its production. Metals like iron, nickel increase biomethane production when present in small amount, at large amount these heavy metals proof harmful for biomethane production [16].

Biogas produced is mixture of many gases like hydrogen sulphide, carbondioxide etc. For biomethane purification $Ca(OH)_2$ is used. Lime water due to absorbance capacity removes H_2S and CO_2 from biogas and purifies it in short duration; however due to lime water saturation absorbance capacity decreases with time [17].

The aim and objectives of this study are

i. To optimize the conditions to produce good amount of biomethane through fruit waste.
ii. To evaluate production of bio methane gas through anaerobic digestion

Purpose of this study is to produce energy from cheap sources and to clean environment from pollution by converting the waste in to useable form. As energy shortage is main problem of our society so to produced energy from fruit waste through anaerobic digestion is easy and cheap method. Purpose of this study is to aware people to use waste for energy production and to inform about the best temperature and pH to achieve maximum biomethane production. Energy production through organic waste also helps in reducing air pollution as CO_2 not released. Waste produced after biomethane production can be used as fertilizer.

2. Materials and Methods

2.1 Sample collection and inoculum preparation

Samples of fruit (grapes, orange, guava, apple, banana, and pomegranate) were collected from different location of Rawalakot Azad Kashmir. Samples were dried and then converted in to powder and saved for further process. For inoculum preparation 20 kilogram of manure and water added and left for two weeks in digester in pH range of 6.5 to 8 and temperature 35°C. Digester consists of electric motor which used for proper mixing. 1 liter of inoculum and 1 kilogram of fruit waste was mixed. Treatment were kept at different temperature like 33°C, 34°C, 35°C, 36°C, 37°C and pH like 6.0, 6.5, 7.0, 7.5, 8.0, 8.5.

2.2 Production and measurement of biomethane

Inoculum and waste was mixed in bottles. Anaerobic digestion process was used. Mesophilic bacteria started to produce biomethane. Bottles were used for biomethane production and biomethane collected in plastic bags. Plastic bags were weigh before biomethane production and then after production. By subtracting the initial and final values amount of biomethane produced were measured.

2.3 Metal detection and purification of biomethane

Metals present in fruit waste were measured. Metals like iron, magnesium, calcium, sodium and nickel were detected by atomic absorption. Substrate was first converted to liquid state through treatment. Two gram of substrate was taken and add 5ml of sulphuric acid and kept at high temperature for 15 minutes in fume hood. Then add perchloric acid in small amount and again provide high temperature for 10 minutes. Biogas consists of different gasses which is hydrogen sulphide and carbondioxide so a method used for its purification. Limewater like $Ca(OH)_2$ solution used for purification of biogas and the $Ca(OH)_2$ solution absorbs the impurities[17].

3. Results

3.1 Biomethane production and purification

Fruit waste was used for biomethane production. Biochemical analysis of fruit waste was carried out to determined fiber, protein, moisture, carbohydrates, ash and fat content result shown in table 1. These parameters play important role in biodegradability of waste. For inoculum preparation mixed animal manure with water and left it for about 20 days at pH ranges from 6.5 to 8 and 35°C in the digester. Different treatments were carried out by mixing 1 liter of Inoculum with 1 kg fruit waste and kept at different temperature and pH ranges result shown in graphs (i-v). Different amount of biomethane is produced from fruit waste at different temperature and different pH but best production of Biomethane was 15.25l/kg/day at pH 8 and temperature 35°C. Biomethane produced consist of many impurities. To remove the impurities lime water $Ca(OH)_2$ was added in bags of biomethane. Flame test was used to check its purification.

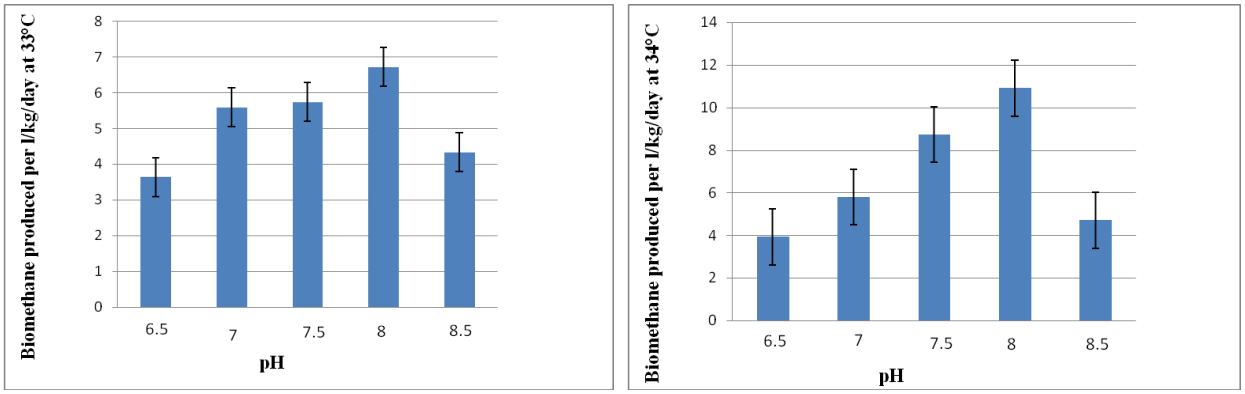
Table 1: Proximate analysis of fruit waste

Parameters	Moisture %	Dry matter %	Crude protein %	Fiber %	Fats %	Carbohydrates %	Ash %
Fruits	12.6±0.7	87.4±0.5	4.3±0.5	8±0.1	2.9±0.1	69.7±1.2	2.5±0.1

Values are expressed as mean ± S.D, n= 3

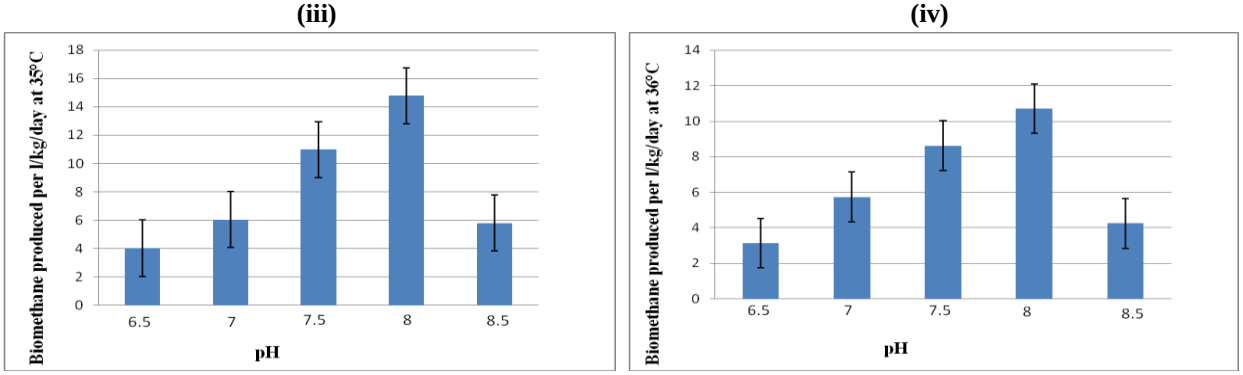
Production of biomethane by using 1 kg fruit waste and 1 liter inoculum at different pH (6.5-8.5) and temperature (i) at 33°C and (ii) at 34°C

(i) **(ii)**



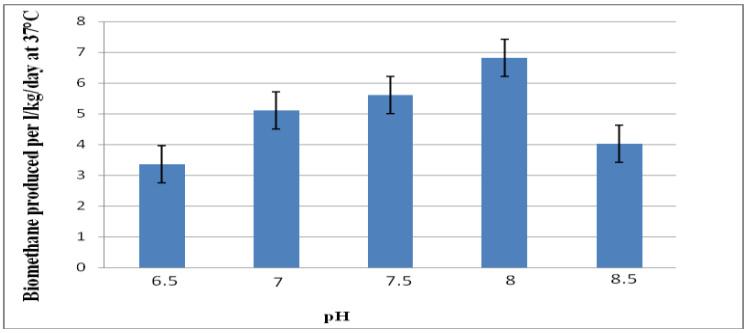
Production of biomethane by using 1 kg fruit waste and 1 liter inoculum at different pH (6.5-8.5) and temperature (iii) at 35°C and (iv) at 36°C

(iii) **(iv)**



Production of biomethane by using 1 kg fruit waste and 1 liter inoculum at different pH (6.5-8.5) and temperature (v) at 37°C

(v)



3.2 Metal detection

Metal concentration in fruits expressed in term of parts per million shown in table 2. Metals play important role in biomethane production. Heavy metals increase biomethane production. If heavy metals present in high concentration, decreases biomethane production. Iron and nickel are important heavy metals increases biomethane production.

Table 2: Metal ions concentration present in fruit waste in ppm

Metal ions	Iron	Magnesium	calcium	sodium	Nickel
Fruit waste	7.1 ±0.1	12 ±0.1	2.6±0.1	7.8±0.1	1.9±0.1

4. Discussion

Best amount of biomethane produced was about 15.25l/ kg/day at 35°C and pH 8. This value is lower than value reported by [18] which is 18.88l/kg/day. This difference was may be due to different nature of substrate used for biomethane production and different weather conditions. Temperature and pH also effect biomethane production. Change in temperature and pH effect bacterial growth which is responsible for biomethane production. Short comes in this study was lack of appropriate apparatus, difficulty in controlling temperature due to uncertain weather conditions and pH. pH decrease during biomethane production it should be necessary to control pH which was difficult task.

All over the world especially in Pakistan energy crises are increasing day by day. It is impossible to fulfill world requirement of energy from these limited natural sources. Our focus shifted towards alternative method for producing energy. Energy production from fruit waste is easy and cheap method. Fruit waste cause pollution so energy production from fruit waste also reduce pollution problem. By optimizing conditions biomethane production can be increased.

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