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STUDIES ON BIOGAS PRODUCTION FROM FRUIT PEELS: BANANA, ORANGE AND PAPAYA PEELS AND THEIR MIXTURE WITH COW DUNG SUPPLEME

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STUDIES ON BIOGAS PRODUCTION FROM FRUIT PEELS: BANANA, ORANGE AND PAPAYA PEELS AND THEIR MIXTURE WITH COW DUNG SUPPLEMENT

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Studies on Biogas Production from Fruit Peels: Banana, Orange and Papaya Peels and their Mixture with Cow Dung Supplement

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DECLARATION

I declare that the thesis submitted is my original work, all the resources and materials used for the thesis development are recognized and cited, and people who involved in are acknowledged.

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ABSTRACT

Deforestation is a very big problem in Ethiopia where most of the peoples depend on firewood for fuel supply. Biogas is a viable alternative source of energy to tackle problems inflicted on the environment by deforestation. Biogas is produced by anaerobic digestion process using any degradable organic substances. Fruits and cow manure are good substrates for anaerobic digestion process which are the main causes of waste management problems. In the present study, banana, orange, and papaya fruit peels with cow dung were subjected to anaerobic digestion conditions for a period of 15 days. A similar anaerobic digestion was performed using a mixture containing equal amounts of the three fruit peels. Each digestion process was done using a 40 L plastic digester charged with 3 Kg of a fruit peel mixed with 3 Kg of cow dung in 18 L of water. Likewise, a 3 Kg mixture of the three fruit peels containing 3 Kg of cow dung in 18 L of water was also subjected to anaerobic digestion. The pH of the anaerobic digestion was measured and recorded as in the ranges of 8 to 5 pH which was convenient for optimum biogas production and the temperature was recorded from between 18^0C to 25^0C. The total amount of biogas produced from the mixed fruit peels was recorded to be 23.2 L while the volume of combustible biogas recorded from banana, orange and papaya fruit peels subjected to a similar anaerobic digestion process was 8.4L, 3.5 L and 4.6 L, respectively. The total percent solid content of banana, orange and papaya fruit peels and cow dung were measured and recorded as 11.85%, 18.73%, 9.43% and 11.3%, respectively. The results obtained show that maximum biogas was produced from the mixture of fruit peels with cow dung.

Key words: Biogas, fruit Peel, Cow dung, Total solid, volatile solid, anaerobic digestion

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ABBREVIATION AND ACRONYMS

AD	Anaerobic Digestion
APHA	American Public Health Association
BP	Banana Peel
C: N	Carbon to Nitrogen ratio
CD	Cow Dung
MC	Moisture Content
FP	Fruit Peels
OP	Orange peel
OLR	Organic loading Rate
PP	Papaya Peel
TS	Total Solid
VFA	Volatile Fatty Acid
VS	Volatile Solid

1. INTRODUCTION

1.1. Back Ground of the Study

Energy is an essential input for economic growth, social development, human welfare and improving the quality of life. Every sector of the economy agriculture, industry, transport, commercial and domestic needs inputs of energy. As a result consumption of energy in all forms has been steadily rising all over the country. This growing consumption of energy has also resulted in the country becoming increasingly dependent on fossil fuels, fuel wood, oil and gases [1].

Almost all the population of Ethiopia is depends on traditional biomass sources using fire wood and charcoal to cover 94% of the energy requirements. The remaining 6% is contributed from petroleum and electricity. Using Fuel wood consumption to this degree is the main cause of extensive deforestation and land degradation [2]. One of the reasons for the decline of land productivity in many areas is the removal of forest and vegetation cover due to increased human population pressure. According to environmental protection authority of Ethiopia, some two million hectares of land in the country has now become irreversibly barren as a result of deforestation [3].

Using biogas as energy source has proven to be an important strategy in solving the problems of energy shortages. Biogas plant is relatively simple, economical and can operate from small to large scale in urban and rural locations. Biogas is a clean burning green fuel used for heating and cooking purpose. Biogas produces sustainable sours of renewable energy [4].

Biogas is a renewable energy which is used to reduce green house gas emissions and dependency on petroleum and wood fuel energy sources. The development and implementation of biogas technologies also used to solve problems such as waste disposal management. The biogas digester can be address by the concept of the four “r” s which stands for reduce, reuse, recycle and renewable energy has generally been accepted as a useful principle for waste handling. Thus the biogas digester can address these principles [5].

Biogas is produced by anaerobic digestion process in the absence of oxygen. Anaerobic digestion is a multistage microbial process which produces biogas and digestion residues as a final product. Biogas is produced from the decomposition of animal and plant wastes. The produced biogas yield mainly contains methane (50-70%), carbon dioxide (30-45%) and other trace gases like hydrogen, hydrogen sulfide, nitrogen, etc [6].

The biogas digester not only provides clean and cheap energy, but also produces a good organic fertilizer for crops and improves the soil fertility, soil structure and yields of crops. Biogas residue is better manure than regular farmyard fertilizer and also reduce the use of chemical fertilize (7)

The production of methane during anaerobic digestion of biologically degradable organic matter depends on the amount and kind of the organic material added to the system. There for cow manure, fruit and vegetable wastes and left over foods are used as the source of anaerobic digestion for energy production in variety of ways. A great option for improving yields of anaerobic digestion is co-digestion of multiple substrates. Using co-substrates in anaerobic digestion system improves the biogas production due to positives synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates (8).

1.2. Statement of the problem

Deforestation is a very big problem in Ethiopia where most of the peoples depend on firewood for fuel supply. In addition¸ deforestation leads to soil erosion and loss of soil fertility. Burning of wood, charcoal and animal dung causes indoor air pollution. The soot and dust which is produced in the burning can go deep in to the lungs causing respiratory infections and also results eye illness and blindness. Wastes of animals and plants are also highly responsible for the cause of waterborne diseases and the causes of sanitation problem [2].

Women and children walking along distance and spend their time to gather firewood for cooking and lighting purpose. To overcome those problems an alternative source of energy is needed. Biogas generation is simple and economical which can plant in large and small scale and generated renewable energy in the form of heat and electricity.

1.3. Objective

1.3.1. General Objective

- The general objective of this study is to evaluate the biogas yield from banana, orange and papaya peels separately and their mixture with cow dung.

1.3.2. Specific Objectives

- To assure biogas production from each fruit peels and their mixture with cow dung.
- To compare the combustibility efficiency of each fruit peel in the presence of cow dung independently..
- To determine the biogas yield from the mixture and each fruit peels with cow dung.
- To determine the total solid, volatile solid, and moisture content.

1.4. Significance of the Study

Tones of waste fruits are leftover in the juice house and expired from the fruit sellers in our city daily. These expired and left over fruits are the main causes of sanitation problem, the place of breading pathogens, Sources of many water borne diseases and they produce a bad odor. There for using these wastes as in the sources of anaerobic digestion in biogas production is the best method of solution for waste management problem. In addition it produces cleaner energy and organic manure.

2. LITERATURE REVIEW

2.1. Biogas

Biogas is a combustible colorless, relatively odorless gaseous fuel that is collected from the microbial degradation of organic matter in anaerobic conditions. Biogas is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases [10]. Biogas is environmentally friendly, relatively cheap and a renewable energy source. The composition of biogas largely depends on the type of substrate used for its formation as well as the conditions within the anaerobic reactor (temperature, pH, and substrate concentration). Generally biogas consisted of methane (50-70%), carbon dioxide (30-40%) and hydrogen, nitrogen, ammonia as well as hydrogen sulphide in a trace amount [11]. The components of biogas are summarized as follows in table 2.1.

Table 2.1: Biogas composition (Surendra et al, 2014)

Content	Formula	Percent composition
Methane	CH_4	50-70
Carbon dioxide	CO_2	25-45
Water vapor	H_2O	2-7
Nitrogen	N_2	< 2
Hydrogen sulfide	H_2S	<2
Ammonia	NH_3	<1
Hydrogen	H_2	<1

2.1.1. Sources of Biogas Generation

Biogas is commonly produced from animal slurry, fruit and vegetable waste, crop residue, sludge settled from waste water and any landfills containing organic wastes. Generally biogas can be produced from almost any organic residue substances [12].

2.1.2. Application of Biogas Plant

Biogas plant produces biogas and bio-manure. Biogas can be used for thermal application like cooking, lighting and heating. It provides a clean gaseous fuel which is used for reducing the cause of climate change. Methane has 20 times greener house gas potential than carbon dioxide, so the capture and burning of methane significantly reduces the green house gas effect [10]. Digested slurry from biogas plant contains enriched bio-manure to supplement the use of chemical fertilizers. It improves sanitation in villages and semi-urban areas by linking sanitary toilets with biogas plants.AD process are also used for the elimination of harmful organisms during in the treatment stages. By the end of 2005, 17 million of family sized low technology digesters were used in China to provide biogas for cooking and lighting [13].

2.2. Anaerobic Digestion

Anaerobic digestion is a biological process where in diverse group of microorganism convert the complex organic matter into mainly methane and carbon dioxide in the absence of oxygen. Anaerobic digestion process passes a series of steps begins with bacterial hydrolysis and ends in methagonesis process [14]. In anaerobic digestion the feed material consists of organic solids, inorganic solids and water. The organic part can only produce biogas while the inorganic material is an affected in the digestion process. An aerobic digestion process is very attractive because it yields biogas, a mixture of methane and carbon dioxide which can be used as renewable energy source and the slurry which is used for fertilizer. Anaerobic digestion occurs naturally in lake and ocean basin sediments, where it is usually referred to as anaerobic activity. This is the source of marsh gas as discovered by Alessandro Volta in 1776 [15].

Anaerobic digestion of organic fraction of municipal solid waste is used in different regions worldwide to reduce the amount of material being landfilled, stabilize organic material before disposal in order to reduce future environmental impacts from air and water emissions and recover energy. Several research groups have developed anaerobic digestion processes using different organic substrates. Anaerobic digestion of organic waste has been widely implemented in the waste stabilization process because of the need to be treated before being disposed in nature [16-17].

2.3. Biological Stages in Anaerobic Digester

Anaerobic digestion is a multi-stage biochemical process in which the complex organic materials undergo hydrolysis, acidogenesis, acetogenesis and methanogenesis in series and each metabolic stage is functioned by different types of microorganisms [18].

2.3.1. Hydrolysis

It is the first stage in an anaerobic digestion process. During the hydrolysis step long chain molecules, such as proteins, carbohydrates and fat polymers are broken down to their smaller constituent parts or monomers such as amino acids, simple sugars, and fatty acids by the the action of extracellular enzymes in the presence of water. Different specialized bacteria produce a number of specific enzymes such as cellulase, amylase, protease or lipase that catalyze the decomposition process. It takes place outside the bacterial cell in the surrounding liquid. Acetate and hydrogen produced in this stage goes to directly to methanogens steps [19, 20].

2.3.2. Acidogenesis

In the acidogenesis step the soluble organic molecules from hydrolysis are utilized by fermentative bacteria or anaerobic oxidizers. Large portion of the monomers (glucose, xylose, amino acids) and long-chain fatty acids are broken down mainly to acetic acid and propanoic acid. Some percent is converted to carbon dioxide (CO_2) and hydrogen (H_2) while the remaining is broken down to short-chain volatile fatty acids (VFA) with one to five carbon (valeric acid, butryic acid, propionic acid, acetic acid and formic acid} [21].

$$C_6H_{12}O_6 + 2H_2 \longrightarrow 2\,CH_3CH_2COOH + 2H_2O$$

$$C_6H_{12}O_6 \longrightarrow 2CH_3CH_2OH + 2CO_2$$

2.3.3. Acetogenesis

It is the third stage of anaerobic digestion process. Intermediates formed during acidogenesis, consist of fatty acids longer than two carbon atoms, alcohols longer than one carbon atom and branched-chain and aromatic fatty acids. These products cannot be directly used in methanogenesis and have to be further oxidized to acetic acid and hydrogen in acetogenesis step [22].

$$CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 2H_2$$

$$CH_3CH_2COOH + 2H_2O \longrightarrow CH_3COOH + CO_2 + 3H_2$$

$CH_3CH_2CH_2COOH + 2H_2O \longrightarrow 2\ CH_3COOH + 2H_2$

2.3.4. Methanogenesis

Methanogenesis is the final stage of anaerobic digestion in which methane forming micro organism utilizes the intermediate products of the previous stages and transforms them into methane, carbon dioxide and water. Two thirds of the total methane is formed from acetic acid and methanol. The other one third of methane produced is due to the reduction of carbon dioxide by hydrogen. Methagenesis is sensitive to both high and low pH. Better yield of methane is produced in the range of pH between 6 and 8 [23]. Methanogenic archea bacteria are more sensitive to changes in temperature than other organisms present in the dige. At higher temperature the acetate oxidation path way becomes more favorable [b].

$CH_3COOH \longrightarrow CH_4 + CO_2$

$CH_3OH + H_2 \longrightarrow CH_4 + 2H_2O$

$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2$

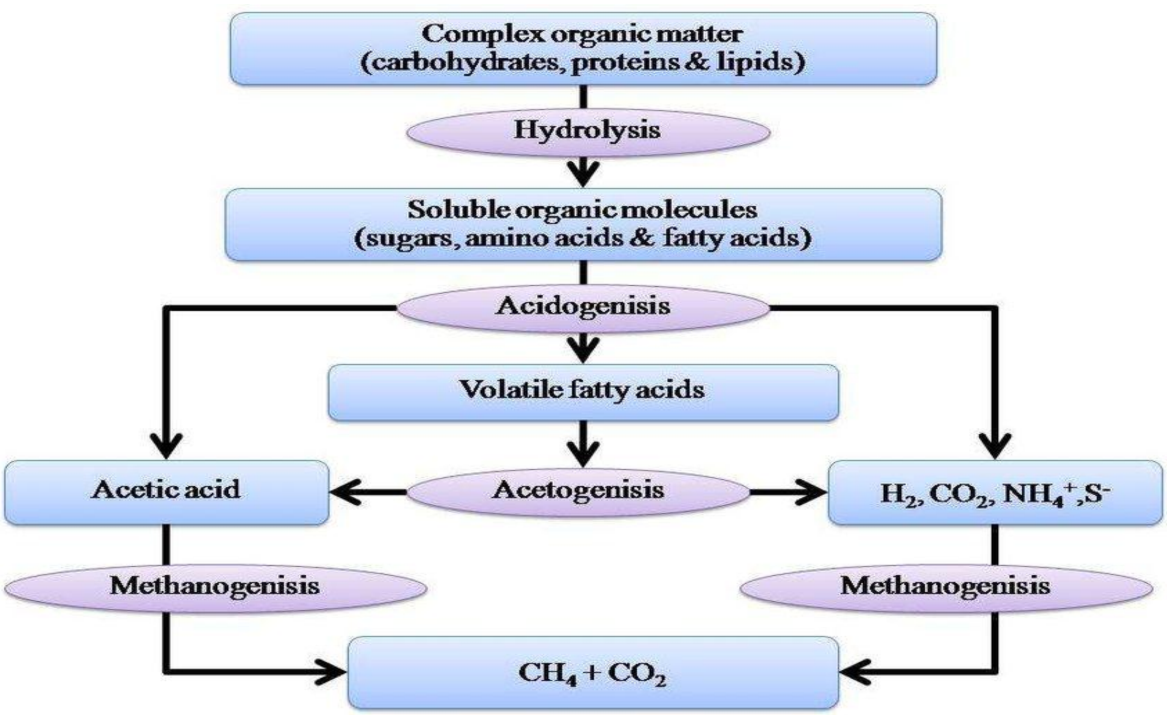

Figure 2. 1: Stages of Anaerobic Digestion (methane fermentation process) (Jarvis, 2004).

2.4. Parameters Affecting Anaerobic Digestion

The biogas generation is highly affected by pH value, temperature, retention time, loading capacity, composition of substrate type, carbon nitrogen ratio, etc.

2.4.1. pH Value

pH is the most determinant factor in an aerobic digestion process. It has been experimentally proved that the biogas production yield and the degradation efficiency is higher for the substrates having a pH range value of 6-8 comparing with other pH range values. The pH value below or above this interval may restrain the process in the reactor since micro-organisms and their enzymes are sensitive to pH deviation. In order to keep the pH in equilibrium condition and to obtain higher yield of biogas a certain amount lime stone or lime is added [24].

2.4.2. Operating Temperature

Like pH **te**mperature is the crucial factor which determines the amount of biogas production. Temperature is an important condition for the survival and optimum flourishing of the microbial association. Bacteria have the following ranges of optimum of temperature.

Cryophilic (Psychrophiles), operating at temperatures from 12 to 24°C, digestion characteristic area under cryophilic regime;

Mesophiles, operating at temperatures between 22-40°C, characteristic area for mesophilic regime digestion;

Thermophiles, operating at temperatures between 50 – 60°C, characteristic area for thermophilic regime digestion.

Hyperthermophilic, operating temperature up to 113^0C.

Generally as the temperature increases the rate of biogas production increases, but at the temperature increases some microorganism began to die which decreases biogas production. Lower temperature also decreases the microbial activity of microorganism which decreases the yield of biogas and if it is lowers than 10^0C the gas production falls sharply and it almost ceases up. Therefore Mesophilic regimes of digesters have very good output efficiency while operated in the temperature range of $25\text{-}40^0$C [25, 26].

2.4.3. Loading Rate

It is another essential parameter in the anaerobic digestion process. It is determined by the measure of the amount of volatile solids in a biological anaerobic digestion system which can be feasible as an input in the system. The loading rate of a system should never be high as it may result in a low or average biogas production. The overloading of a system usually happens due to the presence of degrading or inhibiting substances in the system such as insoluble fatty acids which can cause hindrances in the path of biogas production. High loading causes increase in the amount of acidogenic bacteria which stimulates pH fall and hence results in the elimination of methanogenic bacteria. In the other side a low loading rate will not provide a sufficient quantity of biogas production [27].

2.4.4. Retention Time

Retention time or the residence time in the anaerobic digestion systems is the amount of time a feed stock stays in anaerobic digester. It the average time required for the organic material residing in a digester to decompose to produce biogas. The longer the retention time period; the better is the degradation of the organic matter. Retention time also depends on the operating temperature and content of the solid waste material of an anaerobic digestion system. The retention time for dry system or highly solid wastes are usually more than that of wet system or liquid type waste. organic loading, source of inoculums, temperature, pH, mixing, physical parameters of the reactor (geometry) and the activity of methanogens predominantly determine the retention time or biogas potential in an anaerobic digester [28, 29].

2.4.5. Composition of the Substrate Type

This is another parameter considering the content of the food waste or its composition which may affect the anaerobic digestion in a different way. The rate of methane production potential is depending up on the four major concentrations of wastes which are: lipids, proteins, carbohydrates and cellulose. The anaerobic digestion system having high lipids content usually has high bio-methanization efficiency [30]. Carbohydrates exhibit the fastest conversion rate but the lowest biogas yield with a biogas composition of 50% CH_4 and 50% CO_2. Anaerobic degradation of simple sugar may result in VFA formation and accumulation, leading to a pH decrease and methanogenesis inhibition. On their behalf, proteins represent a fast conversion to biogas and a biogas yield slightly above carbohydrates with methane composition, of 60% CH_4 against 40% CO_2. Finally, lipids show the highest biogas yield, as they have a higher carbon composition which is around 72% CH_4. However fats require longer retention time due to their slow biodegradability [47, 48].

2.5.6 Carbon to Nitrogen (C: N) Ratio

The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of Carbon/Nitrogen (C: N) ratio. The ideal carbon nitrogen ratio for anaerobic bio-digestion is between 20 : 1 to 30:1. If the C: N ratio is very high, the nitrogen will be consumed rapidly by methanogens and results in a lower gas production. On the other hand a lower C: N causes ammonia accumulation and pH value exceeding 8.5 which is toxic to methagonetic bacteria. Optimum C: N ratio of the feedstock can be achieved by mixing waste of low and high C: N ratio such as organic solid waste mixed with sewage or animal manure [31].

2.5. Anaerobic Co-digestion

Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. Animal manure is used as a co-digestion feed stock for most of the digesters currently operating around the world to produce high biogas yield. Although convenient and feasible, animal manure alone may not represent the most efficient way to produce biogas due to manure's inherent deficiency of low carbon to nitrogen ratio [40]. Amending cattle manure with other types of organic waste could improve the biogas production. Substrates dominated by carbohydrates or fats needs to be co-digested or modified by adding fruit wastes, vegetable wastes, food wastes etc. It seemed that carbohydrate rich substrates like fruit vegetable wastes are good producers of volatile fatty acids and that protein rich substrate are yielding good buffering capacity. The high values for the methane yield is an indicators for a high content of biodegradable organic matter in the co-substrate due to an improved ratio of nutrients and better availability of the organic substances [32, 33]

2.6. Types of Digestion Process

Anaerobic digestion can be performed as a batch process or a continuous process.

2.6.1 Batch Digestion Process

In a batch system biomass is added to the reactor at the start of the process. The reactor is then sealed for the duration of the process, when run to completion, emptied and reloaded. It is the simplest form of digestion process. The batch processing needs introduction the inoculation with already processed material to start the anaerobic digestion. In a batch process, the production of biogas is non-continuous. Gas production will peak at the middle of the process and will be low at the beginning and at the end of the process. Typically, in order to ensure a more steady supply of biogas, a number of batch digesters with substrates at different stages of anaerobic digestion are operated in parallel. The efficiency of batch digester is lower than the continuous fermentation process which require larger footprint due to lower organic loading rates than continuously fed reactors batch process requires less pre-treatment and less mixing equipment than a continuous process. This means the digester requires less investment costs, operational skills and surface area [34]. Additionally, batch reactors often suffer from instability in microbial populations, and since AD is a microbial mediated process, the efficiency of the digestion process depends upon the stability of the microorganisms present.

2.6.2. Continuous Digestion Process

In continuous digestion process organic matter is added continuously to the reactor. Here the end products are constantly or periodically removed. Continuous digestion process is more efficient and producing high biogas production. [35]

2.7. Fruit and Vegetable Waste

In developing countries, fruit and vegetable wastes are mainly generated in agricultural production during post-harvest and distribution stages. Fruit vegetable wastes were mixed into municipal waste streams and sent to landfills or incinerators (without energy recovery) for final disposal. However, this is not a good option disposal method , due to its high water content which is in turn, responsible for microbiological instability, formation of odors and the causes the breading of water borne diseases. On the contrary, FVW has a great potential for reuse, recycling, and energy recovery using in biogas technology. Energy could be derived from the fruit and vegetable wastes in the form of biogas and also the by product could be used for soil amendment, which would be beneficial from the view point of both environmental protection and economic development. Fruit and vegetable waste are solid organic waste having high calorific and nutritive value to microbes that's why the efficiency of methane production can be increases by several order. The easy biodegradable organic matter content of vegetables waste with high moisture facilitates their biological treatment and shows the trend of these wastes for anaerobic digestion. Scientific literatures contain several studies on anaerobic digestion of fruits and vegetable waste but just in a few studies have the results been obtained using the fruits and vegetable waste as single substrate. Most literatures also show that anaerobic digestion of Fruit and vegetable wastes without any co-substrate is a challenging task because their high simple sugars often promotes fast acidification of the biomass with a resulting inhibition of methanogenic bacteria activity [42].

2.8. Animal wastes

Animal wastes are important resources that are used to supplement organic matters and improve soil conditions. A significant fraction of cattle dung is used as cooking and heating fuel after making its bricks. However, burning of dung cakes causes serious health and environmental pollution. The burning of animal dung for heating and cooking results higher indoor particle concentrations, Smoke from animal dung based cooking contains carbon monoxide, fine particulates, nitrogen dioxide and hydrocarbons causes acute respiratory infections, chronic obstructive lung disease and cancer [43].

Another important use of cattle dung is its conversion into compost to be used as manure in agricultural fields. For this purpose, cattle dung is heaped in the open and allowed to degrade naturally without any amendments. Further, this method is a major cause of odor and fly problems in rural areas. Animal manure is used as a substrate for biogas production which is reach in nitrogen. Therefore co-digesting with poor in nitrogen substrates can significantly enhance biogas production. During this process, animal dung is converted into slurry which is good quality manure and can be applied in agricultural fields as soil conditioner [44].

3. MATERIALS AND METHODS

3.1. The Study Area

The study was conducted in the main campus of Bahir Dar University in the department of chemistry through the organic laboratory room.

3.2. Sample Collection and Preparation

Cow dung, banana, orange and papaya peels were used as a feed stock for the production of biogas. Fruit peels were collected from the juice house of Bahir Dar city and cow dung was collected from the available animal farm sites near around the university. The collected fruit peels and cow dung were made free from unwanted ingredients like plastics and stones which were not biodegradable. The collected fruit peels were crushed by juice maker in very small pieces to ensure homogeneity and increase the surface area of the substrates for enzymatic action.

A B

C D

Figure 3. 1: Pictures of A= banana B= orange C= papaya peels and D= cow dung

3.3. Methods and Analysis

3.3.1. Materials and Chemicals used

- ✓ **Digester tank and its accessories**: used to precede anaerobic digestion process.
- ✓ **Universal indictor**: used to measure the pH of the substrates inside the digester.
- ✓ **Thermometer**: used to measure the temperature of the slurry
- ✓ **Measuring balance**: used to measure the mass of samples
- ✓ **Oven**: used to dry the samples at a temperature of 105°C.
- ✓ **Furnace**: used to heat the samples at a temperature of 550°C
- ✓ **Water bath and gas jar**: used in the water displacement process.
- ✓ **Measuring cylinder**: used to measure the volume of displaced water.
- ✓ **Juice maker:** for grinding the fruit peels

3.3.2. Components of the Biogas Digester

The major components of the biogas plant consists of

- ➢ A digester tank which hold the slurry.
- ➢ An inlet for feeding the slurry
- ➢ A gas holder tank,
- ➢ An outlet for the digested slurry
- ➢ A gas delivery system for taking out and utilizing the produced gas.

3.3.2. Procedure of the Research Work

For this experiment a 40 ml of small sizes anaerobic floating dome biogas digester were used. 3 kg of small size banana, orange and papaya peels with the co-digestion of 3kg of cow dung was mixed through the three digesters and each substrate dissolve in 18 liter of water and left for 15 days. In the 4^{th} digester tank the mixture of 1 kg of each fruit peel and 3 kg 0f cow dung were added and mixed with 18 liter of water and left for the same duration days.

3.3.3. Determination of the Physico-Chemical Properties of Feed Stocks

Biogas content, total solids, volatile solids, percent total solids and percent volatile solids, moisture content, pH and temperature of each substrate were measured.

3.3.3.1. Determination of Biogas Content

The biogas produced from each anaerobic digestion of the fruit peels with cow dung and the digester which contains mixture of the fruit peels was determined by water displacement method. The weight of the amount of gas produced is equivalent to the amount of water displaced in the water chambers (Archimedes principle of floatation). The amount of biogas produced from each digester was measured in every four days.

3.3.3.2. Total solids (TS) and Volatile Solids (VS) Content

The biogas yield produced is dependent on the total solid and volatile solid content of the substrate. Total solids and volatile solids concentrations of the required substances provide useful information about biogas yield that can be expected and as well as the process. The total solids and volatile solids content determined according to APHA [36].

Determination of Total Solid (TS) Content

Total solid denote organic as well as inorganic matter in the feedstock. It is the quantity of the residue left in the crucible by heating 10 gram of the sample at 105^0C for 24 hours.

The percentage of the total solid is calculated as:

$$\% \text{ Total solids} = \frac{W_{total} - W_{dish}}{W_{sample} - W_{dish}} x100$$

Where

W_{total} is the weight of dried residue and dish (mg)

W_{dish} is weight of dish

W_{sample} is weight of wet sample and dish (mg)

Volatile Solid (TS) Content

Volatile solid represent organic matter of the feedstock. It is the amount of the sample which was determined by heating the total solid or the dried sample at 550^0c for two hours in the muffle furnace.

The percentage of volatile solid is calculated as:

$$\% \text{ volatile solids} = \frac{W_{total} - W_{volatile}}{W_{sample} - W_{dish}} x100$$

Where W_{total} is the weight of dried residue and dish (mg)

W_{dish} is weight of dish

$W_{volatile}$ is weight of residue and dish after ignition (mg)

Determination of Moisture content

Moisture content of the substrates was measured according to APHA. 10g of the slurry was dried in an oven at 105^0C for 24h. The amount of moisture content was calculated as follows.

$$\% MC = \frac{W-D}{W} \text{ X } 1OO$$

Where MC is moisture content

W is initial weight of sample

D is weight of dried sample

3.3.3.3. Determination of the pH and Temperature

The pH and temperature of the anaerobic digestion were measured in every two days. The pH was measured by using a universal indicator and a 30 cm long mercury-in-glass thermometer was used to measure the temperature of the slurry. This measurement was done at specific times of the day.

4. RESULTS AND DISCUSION

4.1. Experimental Results of Total solid, Volatile Solid, Moisture Content and Ash Content of the Substrate

4.1.1. Total Solid Content

The amount of biogas produced is dependent on the total solid and volatile solid of the substrate. According to Paramaguru, et al reported that optimum biogas yield is obtained if the substrate has a total solid of from 10% to 12% [37]. Increase or decrease from the above percent decreases the amount of the biogas product. From the experiment the percent total solid of banana peel (11.85%) was approach to the literature value and orange peel (18.73%) was far from the scientific value. Therefore it can be concluded that banana peel is a good substrate for the anaerobic digestion process.

4.1.2. Volatile Solid Content

Higher percent volatile solid indicates that the substrate contains greater amount of organic part or carbon which produce greater amount of biogas yield [38]. Therefore increase in volatile percent increases biogas production. From the research the volatile solid content of banana peel (92.4%) was highest from the others. Therefore it can be concluded that banana peel considered as an easily degradable fruit that is suitable for biogas production.

Table 4. 1. TS, VS, MC and AC value of the substrates

Substrates	**%Total solid**	**%Volatile solid**	**%Moisture content**	**%Ash content**
Cow dung	11.3	89	88.7	11
Banana peel	11.85	92.4	88.15	7.6
Orange peel	18.73	84.6	81.27	15.4
Papaya peel	9.4	89.2	90.6	10.8

4.2. Temperature and pH Value

4.2.1. Temperature Measurement

The temperature of all digesters was measured in every two days. The recorded value of all the digesters were almost similar, they were measured in the range of 18^0C to 24^0C. According the literature anaerobic digester is effective if the process proceeds in the range of 25^0C to 45^0C temperature. Therefore the temperature of the digesters was not suitable for microorganism production which influenced in the biogas production.

4.2.2. The pH Value

The pH value of all digesters was also recorded in every two days by using universal indicator. At the beginning of the first few days they were measured as about pH of 8 and the pH decrease after some days and recorded as around a pH of 5. The cause of decline of the pH in the digester was probably due to the formation of acids in the acidogenesis process. At the end of the digestion period the pH raised to a pH of 6 which was an indication of ammonia production. The results obtained from the present work were comparable with values reported from the scientific research. In most research works chemical or ash is added to control the pH of the digester. In contrast nothing was added in this research work to keep the decline of the pH during the process. Therefore according to this study anaerobic digestion using fruit peels with cow dung as a substrate can be performed without adding ash or lime.

4.3. Amount of Biogas Content

The amount of biogas produced in a hydraulic retention time of 15 days of the digesters were measured by using water displacement method in every four days and expressed as follows.

Table 4. 2: Total amount of biogas produced from 15 days of hydraulic retention time

Substrates	Weight of a substrate	Amount of biogas produced
Mixture of fruit peels with cow dung	1 kg of each fruit peel and 3kg of cow dung	23.2 L
Banana peels with cow dung	3kg of banana peel + 3 kg Cow dung	8.4 L
Orange peels with cow dung	3 kg Orange peel + 3 kg Cow Dung	3.5 L
Papaya peels with cow dung	3 kg papaya peel + 3 kg Cow dung	4.6L

The onset of gas production was seen starting from the third day of some digesters. Biogas production was confirmed by observing the volume change of the gas container and by burning the produced gas. The amount of biogas yield was increased as the retention time increases and after certain days of degradation time, evolution of gas decreases and finally ceased. The total biogas content from each treatment was measured for about fifteen days of retention time. From the study the mixture of fruit peels with cow dung yielded better amount of gas (23.2L) than the individual fruit peels. Most literatures also show that anaerobic digestion of Fruit and vegetable wastes without any co-substrate is a challenging task because their high simple sugars often promotes fast acidification of the biomass with a resulting inhibition of methanogenic bacteria activity. A great option for improving yields of anaerobic digestion of solid wastes is the co-digestion of multiple substrates in presence of cow dung. Publications on anaerobic co-digestion within the last fifteen years indicated its capability for improving biogas production. In contrast orange peel with cow dung produce smallest amount of biogas (3.5L). According to Sagagi et, al D-limonene is anti-microbial agent which is abundant in orange peel that affects the bacteria growth resulting in the failure of anaerobic digestion [39, 46].

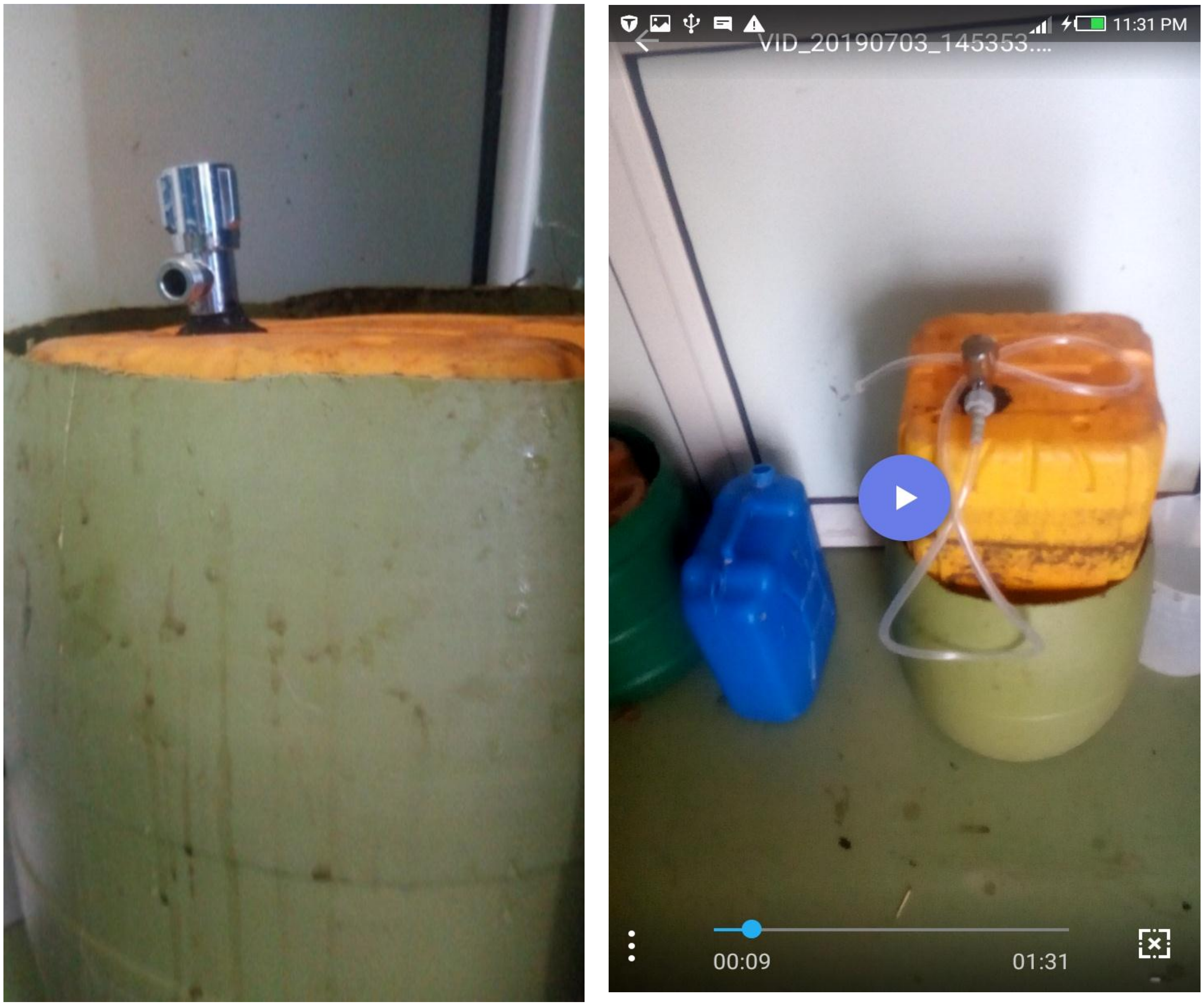

Figure 4. 1: Comparison of the volume of the gas container in the 1st and 7th days of a digestion period.

4.4. Combustibility Test

The combustibility of the gas in the digester was tested by burning the produced gas using a stick match. The biogas of the two digesters which contains the mixture of fruit peels and banana peel was burnt with a blue-white flame effectively but other digesters did not give light with stick match. The length of the burning time differs from digester to digester. The digester which contains the mixture of fruit peels with cow dung was burnt a long time than the digester which contains individual fruit peel with cow dung. From the literature the co-digestion of two or more substrates can produce good yield of biogas.

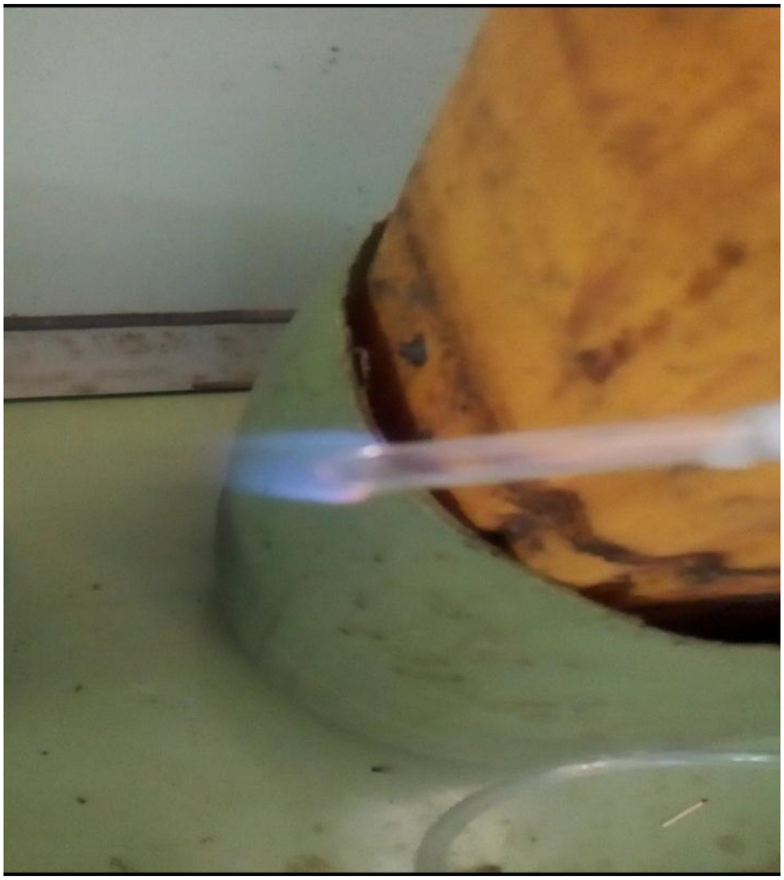

Figure 4. 2: **Flame of biogas produced from mixed fruit peels**

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

From the study it was determined that fruit peels with cow dung are good potential substrates for biogas production even though the amount of biogas production differs from fruit to fruit. This study investigated that the amount of biogas produced was higher when the mixture of fruit peels with the supplement cow dung used as a substrates than using individual substrate. From the literature co-digestion of the feedstock increases the amount of biogas production than using single substrate. The increment of biogas production from the co-digestion of fruit peels were the improvement of nutrients through the anaerobic digestion process. According to the researches cow dung is rich in protein which is used to adjust the carbon to nitrogen ratio. The study temperature was lower than the scientific result which is needed for an aerobic digestion to produce sufficient amount of biogas. The pH of the digester was also measured and obtained a value between a pH of 5 to 8 where the result coincides with the literature value. There for it can be concluded that pH of the digester did not affect the amount of biogas obtained from the study.

5.2. Recommendations

Using fruit wastes extensively for anaerobic digestion process not only produce biogas but also a better solution for waste management problem. Therefore it is recommended that further experiment on biogas production from fruit peels cloud be carried out**.**

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