Effect of Biomass Composition and Operation Condition on Methane Yield from Anaerobic Digestion

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Abstract

The amount of biomass waste is rapidly increasing worldwide. Besides, the energy demand is also increasing. Utilities biomass for production of biogas is one of the most promising methods for producing energy renewable resource. This project aims at investigating yield and composition of produced biogas produced from anaerobic digestion for single feed stock (cow manure, fruits and vegetables waste) and combined feed stock. Samples of biomass were collected from different sources, and their properties including pH, TS, moisture content and VS were measured. The result showed optimum values for characterization test of biomass samples. Digestion process will proceeded under mesophilic condition by using batch bioreactor. For each biomass two vessels were used, first one for digestion process and the second for collect produced biogas. Water displacement method, BIOGAS 5000 device were adopted to determine the yield of biogas and its composition respectively. Biogas composition were not satisfying where the highest percent methane is only 4% of fruit and vegetable due to acidic ambient which hardly affects methanogenic bacteria, 30% of cow manure due to leakage in reactor body and 1% of co-digestion because oxygen and pH value were the main reasons for inhibition of the anaerobic digestion process.

الإهداء

إلى فلسطين ودُرَتها القُدس وَ تاجُها الأقصى

وَ لِمَن افتَداها بِروحِهِ فارتَقى شَهيدا

وَ لِمَن ضَحى لَها بِسنين عُمرهِ فَغدى أَسيرا

وَ لِكل المُرابِطين على ثَراها الطاهِر.

إلى مَن قَضى اللهُ تَعالى في كِتابِهِ الإحسان إِلَيهِما

مَع تَوحيده بِالعُبودية فَلا نَستَطيع رَد نزر مِن إحسانِهم إلَينا

" أَبي وأُمي

أَنتُما حَياتي كُلها, لَكُم مِني فُؤادي فاقبَلوه ....

إلى مَن وَقَفَ على المَنابِر وَ أَعطى مِن حَصيلة فِكره لِيُنير دُربنا ...

إلى الأساتِذَةِ الكِرام ...

لِكُل مَن دَعمَنا وَ وَقَفَ بِجانِبِنا...

لِزَميلاتِنا وَ زُمَلائِنا مُهَندِسي وَ مُهَندِسات المُستَقبَل ....

إليكُم جَميعاً نُهدي فاتِحَة العَطاء ....على أَملِ البَقاء بِإذنِ الله تَعالى

الشكر

الحمد لله الذي بفضله تتم النعم والصالحات ...الحمد لله الذي أنار قلوبنا وعقولنا

الشكر لله , واهب عقلنا , رازقنا نعمه ... الشكر لله أولا و أخيرا على حسن توفيقه وكريم عونه

الشكر لكل من علمنا حرفاً .... لكل من أنار دربنا ولم يبخل علينا بمعلومة او بعلم

الشكر لوالدينا الاعزاء .... شكرا لثقتكم و دعمكم لنا

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Chapter One

Introduction

1.1 Introduction

The global energy demand is rapidly increasing. The energy demand is mainly fossil fuels which include: crude oil, coal, natural gas and others .The burning of fossil fuel releases greenhouse gases (GHGs) such as: CO_2, N_2O and SO_2 to the atmosphere. These gases, act like a blanket around the earth, preventing heat to escape out of the atmosphere resulting increase in the average temperature of the Earth, what is called global warming. The global warming leads to several environmental problems include: rising sea levels due to the melting of the polar ice caps, which may cause flooding, furthermore ,GHGs mix with the clouds it leads to acid rain, which adversely impacts on the surface waters, aquatic animals, soils, forests and it may buildings damage, moreover it has impacts on human health.

One of the approaches to reduce the GHGs and the large amount of biomass waste is to replace the nonrenewable energy rescores with green and renewable ones such as biofuel-biogas energy. The production of biogas is mainly achieved through anaerobic digestion(AD) of biomass waste in bioreactor. Biomass is a material and substance derived from living organisms which originating from forestry and agriculture, along with industrial and municipal residues and wastes, such as animal manure, slurries, food industry and others.

AD is a biochemical process decomposition of organic matter, in the absence of oxygen by various types of anaerobic microorganisms in digesters. Digestion process proceeded during four steps: hydrolysis, Acidogenesis, Acetogenesis, Methanogenesis[1]. Hydrolysis: organic matter is decomposed into smaller units. Whereas, acidogenesis: the products of hydrolysis are converted into methanogenic substrates. While during Acetogenesis: Products which cannot be converted during acetogenesis into methanogenic substrates converted in this stage. The last step will be methanogenesis: in which methanogenic bacteria carry out methane and carbon dioxide which have produced. AD process is Controlled by many parameters such as oxygen, temperature, pH, volatile fatty acids (VFA), ammonia, macro – and micronutrients ,and also by operational parameters for example: organic load, hydraulic retention time (HRT) and economic feasibility[1]. The main output of AD process is biogas (CH_4, CO_2, H_2S) and natural fertilizer (digestate) for agriculture.

The current study aims at investigating the effects of type of biomass and operation condition on methane yield. Different types of biomass will be used in batch experiment using batch bioreactor and the result will be used to design a pilot scale bioreactor to study the effects of type of biomass on methane yield.

1.2Scientific background

Anaerobic digestion is the biological treatment process convert organic substrates to biogas in the absence of oxygen, during four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis for completing AD reactions .Producing biogas which is a mixture of gaseous compounds, principally methane (CH_4) and carbon dioxide(CO_2) [2].Digestion of organic matter offers several environmental, agricultural and socio-economic benefits throughout improved fertilizer quality of manure, substantial reduction of odors and inactivation of pathogens also biogas production as clean, renewable fuel, for multiple utilizations[3].Different substance could be used as feed stock for anaerobic digestion. Component of those feed stock is mainly single component and multi-component is performed to study the possibility of improving methane yield. According to Tjalfe G. Poulsen et al.(2010)multi-component substrates increases the methane yield much more than what would be expected from digestion of single substrates[4].

In the early days, application of anaerobic digestion was for the treatment of domestic and animal waste. Presently, the process has been widely used for treatment of municipal sludge and industrial waste in developed countries. Due to threatening on solid waste management for final disposal, municipalities are looking for better solution and many research works are going to anaerobic digestion for its stable performance. Due to the increasing in application of anaerobic digestion, different biogas measurement methods with different principle have been used [4]. The water displacement method is a volumetrically method where produced biogas kept under constant pressure to allow measure of biogas [5]. Water displacement meter is simple, economic and they can work for a long period of time without maintenance[6].

Anaerobic Digestion process is efficient treatment process for organic substance. Although, biogas production is highly affected by changing one or more of those parameters; pH values ,temperature, C/N ratio, OLR, retention time[7], moisture content [8] and Substrate/carbon

Source. In order to get the highest biogas and methane yield operating parameter should adjusted to the optimum level.

In this project different biomass would be used as single and combined feed stock, biogas yield and its composition is determined by water displacement method

1.3 Research question

1.3.1 Main research question

What are the effects of biomass type and operation conditions on methane yield in bioreactor?

1.3.2 Sub-questions

1. How do the pH, temperature and moisture content affect biogas production and methane yield?
2. What is the composition of the produced biogas?

1.4 Goals and Objectives

The main goal of the present study is to investigate the effects of type biomass and operation conditions on methane yield released from anaerobic digestion.

The project targets the following specific objectives:

- To study biogas and methane yield production for many types of biomass.
- To identify and analysis the parameters such as temperature, pH value and moisture content that affect process and methane yield.
- To study and analysis the composition of the produced biogas.
- To study co-digestion process and its effect on methane yield production.

1.5 Significant of study

Biogases is a promising technology have advantages and benefit for the society. Biogas represents a flexible and efficient renewable energy source that reduced dependency on imported fossil fuels, reduced greenhouse gas emissions and mitigation of global warming. Also usage of organic waste in biogas production helps in waste reduction and job creation.

1.6 Research Methodology

The following methodology will be adopted to determine the effect of biomass on biogas yield:

1. Quantitative and qualitative survey for organic waste in Hebron Governorate Collect suitable biomass depends on its abundance and expected methane yield.
2. Characteristics of collected sample as moisture content (MC), pH, volatile solid (VS) and total solid (TS) will be defined by lab experiments.
3. Batch experiment using batch bioreactor vessels will be performed using collected samples with certain characteristics.
4. Documentation of project thesis.

1.7 Budget

The following table (1) list that the total cost for the project is about 1000$.

Table 1: Budget table

Steps	Cost($)
Preparation of material and equipment	350
Transportation	100
Total cost	450

1.8 Action Plan

The action plan of our project is illustrated in table (2) below.

Table 2: Action plan for the first semester

TASKS	1st Month				2nd Month				3rd Month				4th Month			
	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$	Wk$_1$	Wk$_2$	Wk$_3$	Wk$_4$
Identification of Project Idea	■	■														
Literature Review			■	■	■	■	■	■	■	■	■	■	■	■	■	
Preparation of equipment					■	■	■									
Documentation							■	■	■	■	■	■	■	■	■	
Presentation of First Semester																■

Table3: Action plan for the second semester

TASKS	1st Month				2nd Month				3rd Month				4th Month			
	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4
Bioreactor Design																
Collection and preparation samples																
Start fermentation process																
Monitoring process conditions																
Documentation																
Presentation of second Semester																

Chapter two

Literature Review

2.1 Introduction

Biomass is a primary source of energy that contain organic matter can be derived from any organic substance such as sludge organic industrial waste, organic domestic waste and by cultivation of dedicated energy crops. All type of biomass could transfer to more useful form of energy by using one of transformation methods. Anaerobic digestion (AD) process is one of those alternatives where organic fraction degraded by different type of microorganism. Degradation is happen in linked four steps hydrolosis, acidogenesis, acetogenesis, methanogenesis. Three product released from those stages; bio-gas with 35% of overall product, digestion residues (digestate) with 65% of overall product, waste water. The most important product of AD is biogas that contains high potential of energy saved in methane compound and other gas such as CO2. Productivity of biogas could be optimized by changing many parameters such as temperature, pH, C/N ratio, organic loading rate (OLR), retention time and source of organic matter which could be single source or combined source. Also digestion reactor design one of important thing that should be tack in consideration.

In this chapter different methane yield for deferent biomass have been discussed. Moreover, parameter, inhibitor, involved microorganisms, process stages, digester design of anaerobic digestion process will be discussed also.

2.2 History and future trend of biogas

Historically, methane was discovered as flammable material for first time in1776 in Europe by Aless and roVolta. Researchers make an effort to clear chemical stricture of methane, the last formula was provided by Avogadroin 1821. After this detection, yield of methane (biogas) production gradually increased. In 1884 Louis Pasteur together with his student Gavon managed to produce 100 L methane from 1 m^3 dung fermented at 35°C.Pasture experiment encourage production of biogas using deferent biomass for many purpose. For example gas from waste water treatment was used in1897 to running on the street lamps of Exeter city. Also around (1930-1940) agricultural waste was used to produce biogas spicily in small city and town mainly in Europe.

Up to date stabilization of biogas plant is increasing in high rate in Europe due to legislation that supporting of biogas production figure (1).In other country such as China, India, Nepal, Vitamin production of biogas from small scale household biogas plant is highly spread. Palestine has high potential of biogas production due to high amount of available biomass [9]. Researcher estimate amount of biogas produces from different type of animal's excrete from house hold in Palestine depending on data in table(4) shown below [10]. Their result show that 330,000 kg per day of cattle manure and 100,000 kg of goat and sheep manure per day could produce 12,416 m^3 of biogas per day. 10-20% of energy need for cooking in rural area could be covered with this amount of biogas.

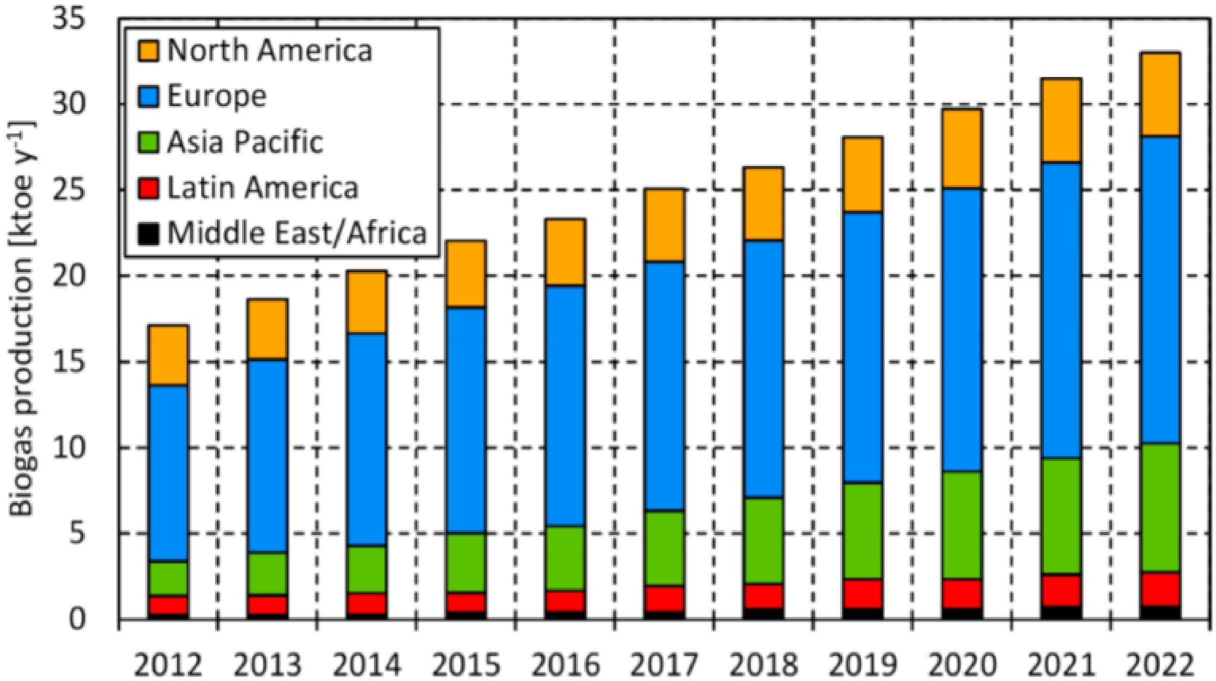

Figure 1 :Biogas production at 2012 and trend to 2022 in different areas of the world[11].

Table 4:Number of cattle in the Palestinian Territories by type in years 2007 and 2008 [10]

Livestock type	Number of heads	kg manure / day
Cattle	33,000	330,000
Goat	322,000	100,000[1]
Sheep	689,000	

[1] Summation of goat and sheep manure

2.3 Substance and biogas yield

Biomass is a term for all organic material that stems from animals and plants (including algae, trees and crops) [12, 13]. There are three categories of biomass; industrial by-products, substrate of farm origin and waste from private households and municipalities. In general all type of biomass could be used as substance or as feed stock in AD process as long as they contain carbohydrate, protein, fats, cellulose and hemicelluloses as main component [13].

2.3.1 Agricultural residues

The feedstock substrates used for biogas are derived from the agricultural sector, which accounts for the largest potential for biogas feedstock [14] .These feed stocks consist mainly animal manures and slurries collected from farms (from cattle, pigs, poultry, etc.) , crop residues (e.g. straw, grasses, leaves, fruits, whole plants) and energy crops (maize, grasses, beets, sunflowers, etc.) grown specially for biogas production[15].

1. Crop residues

Large quantity of crops residues are produced annually worldwide and often dumped in open environment. These include non-food based portion (complex carbohydrates) of crops (such as cereal crops straw, rice husk, bagasse, maize cobs, coconut husk, groundnut and other nutshells and sawdust)[16]. The Food system of humankind depends on four staple crops maize, wheat, rice, and sugarcane where the majority of crop residues released from. For example 20–25% of annually rice production (161.420 million tons) goes as disposed rice husk[16]. Plant biomass is mainly composed of cellulose, hemicelluloses and lignin along with smaller amounts of pectin, protein, extractives (soluble non-structural materials such as sugars, nitrogenous material, chlorophyll and waxes) and inorganic minerals. Due to exclusive properties like Containment of lignin, most of time crop residues need special pretreatment before using it as source of energy[16]. Chandrat et al. (2011) reviewed mane characteristics of crops waste table (5) show those characteristics.

Table 5:Volatile fraction in dry matter for crop residues

Waste type	Volatile fraction in dry matter, %
Sugarcane bagasse	70.9
Sugarcane leaves	77.4
Maize stove	75.2-93.2
Wheat straw	79.6-91.3
Rice straw	69.3-95
Rice husk	59.5-75.7

2. Energy crop

Energy crops are specifically grown to produce some form of energy[17]. Energy crops could be classified depend on chemical structure; herbaceous and woody crops or depend on intended end-use; Oil crops, Ligno-cellulosic crops and Sugar and starch crops which used for biogas production [17, 18]. In general, the characteristics of the ideal energy crop are: high yield (maximum production of dry matter per hectare), low energy input to produce, low cost, composition with the least contaminants, low nutrient requirements [12]. Maize, sunflower, grass are the most commonly used energy crops due to their characterized with those characteristics [19]. Many researchers make effort to investigate ability to use energy crops as biogas feedstock. Table (6) show methane and biogas yield for many energy crops.

Table 6:Methane and biogas yield for many energy crops

Feed stock	Reactor mode	Temperature	HRT	Methane yield	Reference
grass silage	Batch	(36°C)	--	319 ± 19 L /kg VS	[20]
maize silage	Batch	(36°C)	--	307 ± 21 L /kg VS	[20]
silage and hay	Batch	(36°C)	--	296 ± (31) L /kg VS	[20]
Maize	Batch	(38°C)	60	$1.663*10^{-7}$ L /kg VS	[21]
Grass cuttings	Batch	(40°C)	65	370 L /kg VS	[22]

3. Animal manure and slurries

Animal farming is an important part of the agricultural sector in most countries . Manures and slurries from various animals can be used as feedstocks for biogas production (pigs, cattle, poultry, horses and many others). They are characterized by different dry matter contents: liquid slurry (below 10% dry matter) and solid manure (10–30% dry matter) [15]. Their composition also differs according to the species of origin and the quality of the animal feed. Manures have low carbon to nitrogen (C:N) ratio , high buffer capacity and able to stabilize the AD process when the pH decrease inside the digester . Moreover, manure rich in various nutrients necessary for the growth of anaerobic microorganisms. Manures have a highest potentials as a feedstock for biogas, but their relatively low methane yield does not provide economic sustainability of mono digestion, so they are dependent on co-digestion with co-substrates with a high methane yield in order to enhance the methane yield and economic efficiency of manure mono-digestion and results in a higher stability of the AD process. Manure is often co-digested with co-substrates characterized by easily digestible organic wastes, high C/N ratio and poor buffer capacity and producing large amounts of volatile fatty acids (VFA) during the AD process. Most co-substrates used are agro-industrial waste (47%), followed by OFMSW (12%), crude glycerol (GLY) (9%), cheese whey (5%) and olive mill waste (OM) (4%)[7].Methane yield for excreta of animal and mixture of excreta of animal and other material shown in table (7) have been shown and table (8).

Table 7**:**Methaneyield from Excreta of animal

Feed stock	Reactor mode	Temperature	HRT	Methane yield	Reference
Cattle slurry	Batch	(36°C)		238± (42)L /kg VS	[20]
	Batch	(35°C)	48	133 ± 15 L /kg VS	[23]
	Batch	(40 °C)	65	151 L /kg VS	[22]
Chicken litter	Batch	(35°C)	48	105 ± 9 L /kg VS	[23]
Chicken manure	Batch	(40°C)	65	210 L /kg VS	[22]
Sheep manure	Batch	(35°C)	48	105 ± 7 L /kg VS	[23]

Table 8: Methane yield mixture of Excreta of animal and other material

Feed stock	Reactor mode	Temperature	HRT[g]	Methane yield	Reference
a	Batch	(35°C)	48	268 ± 38	[23]
b	Batch	(35°C)	48	196 ± 10	[23]
c	Batch	(35°C)	48	220 ± 21	[23]
d	Continuous two stage	(35°C)	--	0.26[(2)]	[24]
f	Continuous	(47°C)	--	0.32 [(2)]	[25]

a) 32 % chicken litter + 12 % sheep manure + 24 % food wastes + 32% leaves/straw (by weight). b) 80% cow dung + 20% M0. c) 55 % cow dung + 45 % M0. d) 50 % Cow manure +50 % Cheese whey. f) 27% cow manure + 73 % fruit and vegetable waste. g) Hydraulic retention time.

2.3.2 Sewage sludge (SS)

Primary and secondary sludge resulting from the aerobic treatment of municipal wastewater can be used as biogas feedstock. Sewage sludge has a methane potential similar to animal slurries. It is characterized by low (C/N) ratios ranged from 6 to 9, which negatively impact the efficiency of anaerobic digestion. Excessive nitrogen and insufficient carbon mean an imbalance diet for microorganisms, and possibly result in ammonia accumulation and subsequent inhibition to microbial activity[26]. Moreover sewage sludge has low organic content, high buffer capacity and contains compounds such as heavy metals, pharmaceuticals, pathogens and biologic and chemical pollutants. Therefore the countries in which use of digested sewage sludge as a fertilizer or for other agricultural purposes is banned, while in other countries its utilization as a fertilizer is controlled by strict requirements concerning the limit values of concentrations of heavy metals and persistent organic pollutants as well as the sanitation requirements for inactivation of pathogens and other biologic vectors[27].Some important characteristics and methane yield for sewage sludge has been shown in table (9)sewage sludge is often co-digested in order to improve the biogas yield and the process stability with co-substrates such as easily biodegradable organic matter, high C/N ratio[26]. Low alkalinity values and leads to dilute some undesired compounds present in SS such as heavy metals, pharmaceuticals and pathogens.

It is often co-digested with manure or/and organic wastes from industries and households, which improves the biogas yield and the process stability[28].

Table 9: Characteristics and methane yield for sewage sludge

	DM[a](%)	VS[b] % of DM	VS (%)	Methane yield	Reference
Waste water sludge	5	75	3.75 0	400	[15]
Wastewater sludge[c]	10	75	7.5	400	[15]

a)Dry matter. b)Volatile solids. c) Concentrated Wastewater sludge

2.3.3 Residue of food industry

1. Olive oil industry

waste of olive oil production are composed of solid wastes consisting of olive pulp and pits left over after pressing the fruits, as well as liquid wastes consisting of vegetable and additional water generated during decantation[29]. Liquid waste is known as olive-mill wastewater (OMWW), which consists of substantial amounts of added water, olive juice combined with small amounts of unrecoverable oil, and fine olive pulp particles. Liquid waste from the olive oil industry is a dark-colored juice, which contains organic substances such as sugars, organic acids, poly-alcohols, pectin, colloids, tannins, and lipids with low pH). The difficulty of disposing of OMWW is mainly related to its high BOD and COD[23].Table(10) show important characteristics for olive oil mill[29].

Table 10:Important characteristics for olive oil mill

Parameter	Value
COD	5 and 25 g $L^{-1(a)}$ / 50–90 g $L^{-1(b)}$
pH	3-5.9
COD/BOD	2.5 -5
TS	20 g L^{-1}
Ash % wt	7.10–7.46

a) Two-phase process. b) three-phase process

2. Fruit and vegetable industry

Fruit and vegetable industrial solid waste include items removed from fruits and vegetables during cleaning, processing, cooking, and/or packaging. These items may include leaves, peels, skins, rinds, cores, pits, pulp, stems, seeds, twigs, and spoiled fruits and vegetables [30]. generally, those residues consist of carbohydrate as a main component beside relatively small amount of fat and protein and have high content of moisture, fiber, BOD, COD and characterized by variation in pH [31]. Table (11) shows main characteristics for mixture of fruit and vegetable. Also fruit and vegetable waste (FVWs) have high Degradability where 50% of FV was degraded at 2 h, and more than 80% was degraded at 24 h for all periods[32]. Asquer et al. (2013) demonstrate that biochemical processes, such as anaerobic digestion the most suitable conversion technologies to treat FVWs. Indeed, they have optimal moisture and Volatile Solid contents [33]. Table (12) show methane and biogas yield for different type of fruit and vegetable.

Table 11:Characteristics for mixture of fruit and vegetable

Parameter	Percent	Reference
Total solid	8-18%	[34]
Total volatile solid	87%	[34]
Moisture content	80-90%	[35]

Table 12:Methane and biogas yield for different type of fruit and vegetable

Feed stock	Reactor mode	Temperature (°C)	Period of time (day)	Methane yield L /kg VS	biogas yield	Reference
(FVW)	Batch	--	47	160	0.16(3)	[36]
	Continuous	(37°C)	2-2.3	420	--	[37]
VW	Batch	(35°C)	30	387	--	[38]
FW	Continuous	(37°C)	20	52%	--	[39]

Food waste	Batch	(40°C)	65	624	--	[23]
0.15[1]	Batch	(37°C)	28	114.5	182	[40]
0.15[2]	Batch	(55°C)	25		133	[40]
0.5[3]	Batch	(37°C)	27		84	[40]
	Batch	(55°C)	19		16	[40]

1,2,3 is weight of palm fruit waste/weight of waste

3. Meat and poultry industry

Solid waste from the meat processing and rendering sector is comprised primarily of slaughterhouse waste. Wastewater from a slaughterhouse can contain blood, manure, hair, fat, feathers and bones. The quantity of waste generated and the characteristics of the waste depend on the kind of meat being processed. Characteristics of waste water released from slaughterhouse summarized in table (13).

Table 13: Characteristics of slaughterhouse waste water

Parameter	Value
COD mg O_2/L	3,756+687
BOD mg O_2/L	1,873+421
pH	7.19+ 0.06
BOD/COD	0.5

4. Dairy industry

Water is a key element in dairy industry .dairy wastewater characterized as strong industrial waste water due to high COD and BOD content, high level of dissolved or suspended or volatile suspended solid. Diary effluent composed of lipids, protein, highly degradable carbohydrate, those components mainly derived from milk and milk products such as cream, cheese or whey.

Table (14) show important characteristics of dairy industry waste water taken from several factory [41]. Under anaerobic fermentation carbohydrate and protein in dairy wastewater is a readily available substrate for anaerobic bacteria but lipids work as inhibitory compounds through anaerobic fermentation because of its low adsorption rate by methanogens bacteria [41]. Methane for some diary industry has been shown in table (15).

Table 14:Characteristics of dairy industry waste water

Effluent type	COD (mg/l)	Total solids (mg/l)	VSS (mg/l)
Mixed dairy processing	1150–9200	2705–3715	255–830
Mixed dairy processing	63100	53000	12100

Table 15: Methane for many diary industry

Feed stock	Reactor mode	Temperature (°C)	Period of time (day)	Methane yield L /kg VS	Reference
cheese Whey	Batch	(40°C)	40	501	[42]
	Continuous		20 (HRT)	6.7(1)	[43]
Raw milk	Batch	(36°C).		512	[20]
Sour cream	Batch	(36°C).		714	[20]
Cottage cheese	Batch	(36°C).		602	[20]
Buttermilk		(36°C)		489	[20]

2.3.4 Municipal solid waste

Municipal Solid Waste (MSW) is those items we use every day and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses [30].

50-55% of municipal solid waste is organic material that composed from fruit, vegetable, food and biodegradable waste .in municipal waste management anaerobic digestion play important role to dispose the organic fraction of MSW (OF-MSW)[44]. Table (16) summarize the main property of OF-MSW[45].

Table 16:The main property of OF-MSW

Parameter	Average value
TS g/kg	763
TVS % TS	43.9
TOC % TS	19.3

2.4 Biochemical Process of Anaerobic digestion

Anaerobic digestion (AD) is complex linked processes in which obligatory and facultative bacteria tend to degrade organic material under anaerobic condition (in absence of oxygen) [13]. AD steps begging with hydrolysis then acidogenesis, acetogenesis, methanogenesis have been shown in figure (2) [46]. Degradation process produces three product; biogas with 70%methane and CO_2 29%, wastewater and the nutrient-rich digestate which could be used as fertilizer [13, 47].

2.4.1 Hydrolysis

hydrolysis is the first step in which AD facultative and obligatory microorganisms tend to convert insoluble complex organic material to soluble compound (monomers)using specialized hydrolytic exoenzymes (hydrolase) as shown in equation (2.1) and equation (2.2)[13].Those enzymes considered as biochemical catalysts that use water to cleave chemical bonds [48].

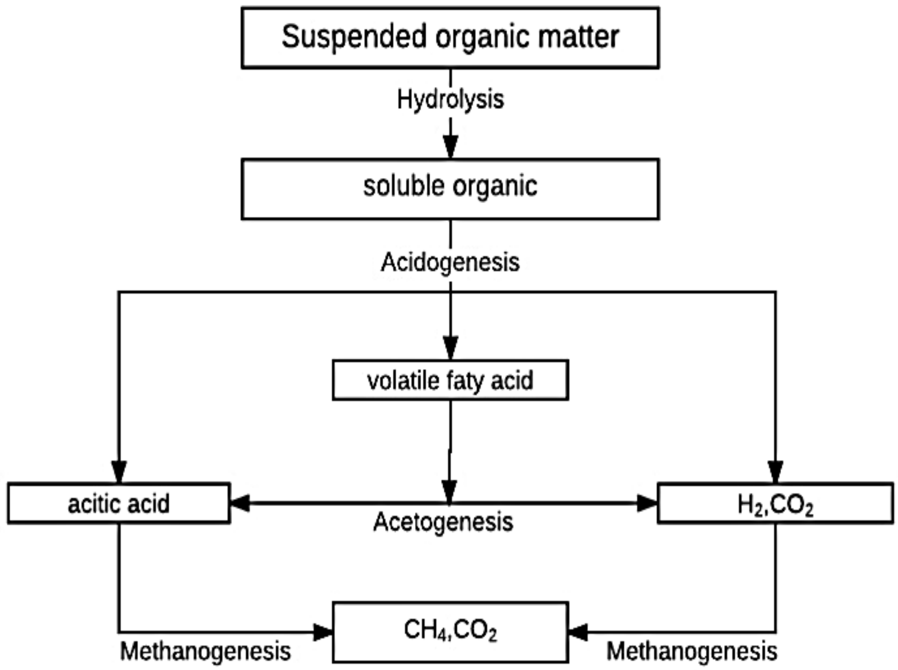

Figure 2: Subsequent steps in the anaerobic digestion process [46]

In such enzymatic reaction Carbohydrate (Polysaccharide), protein and fat (lipids) degrade to monosaccharide's, amino acids, long chain fatty acids and glycerol respectively [13]. Hydrolysis of carbohydrate take place within a few hours, and hydrolysis of protein and lipids tack few days to decompose [13].special type of carbohydrate such as lignocellulose and lignin fibrous degraded only slowly and incomplete due to packing them tightly in lignin therefore difficult for bacteria to get at [13, 49].Hydrolysis process is the slowest reaction in overall anaerobic digestion. Thus it consider as overall rate-limiting step in AD. Sanders et al. (2000) show that at constant pH and temperature the key factor that control the hydrolysis rate is the amount of substrate surface available for hydrolysis[50]. In a larger surface and therefore an increase of hydrolysis rate (g/l/day) [50].

$$\underbrace{complex\ organic\ matter}_{suspended\ organic} \xrightarrow{Hydrolysis(enzimatic)} \underbrace{simple\ organic}_{solube\ organic} \quad 2.1$$

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{10}} + H_2O \xrightarrow{\text{Enzyme(invertase)}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6} \quad 2.2$$

2.4.2 Acidogenesis

In this stage, the hydrolyzed compounds are fermented into volatile fatty acids (VFA) (acetic, propionic, butyric, valeric acids etc.), neutral compounds (ethanol, methanol), ammonia, and the pH falls as the levels of these compounds increases. Carbon dioxide and hydrogen are also evolved as a result of the catabolism of carbohydrates. The group of microorganisms responsible for this biological conversion is obligate anaerobes and facultative bacteria, which are often identified in the literature as acidogens. The specific concentrations of products formed in this stage vary with the type of bacteria as well as with culture conditions such as temperature and pH [51]. Typical reactions in the acid-forming stages are shown below in equation (2.3), glucose is converted to ethanol and carbon dioxide equation (2.4)

$$\underbrace{soluble\ organic}_{amino\ acid, fatty\ acid} \xrightarrow{Acidogens} \underbrace{intermidiate\ compound}_{cetic, propionic, butyric, valeric\ acids} \qquad 2.3$$

$$\mathrm{C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2} \qquad 2.4$$

2.4.3 Acetogenesis

The third step is acidogenesis. Obligatory H_2 producers microorganisms(acetones microorganisms which have ability to produce acetate)further degraded VFA, alcohol,$CO_2$and H_2that produced in acetogenesis step to acetic acid equation (2.5) and equation(2.6). Other by-product such as CO_2,H_2could be produced also.

$$\text{butric acid, proponic acid , Valeric acid etc.} \xrightarrow{\text{acetogen}} \text{acitat} + \mathrm{H_2} + \mathrm{CO_2} \qquad 2.5$$

$$CO_2 + H_2 \xrightarrow{\text{acetogen}} \mathrm{CH_3COOH + 2H_2O} \qquad 2.6$$

Partial pressure of hydrogen (H_2) in the system considered as specialized growth limitation to acetogenesis process. In each time that acetogen degrade molecule of butyric acid, proponic acid and valeric acid, hydrogen molecule will be produced[13], with continuing the degradation process concentration (partial pressure) of H_2 would increase.Those microorganisms highly affected by high partial presser of H_2 where it can complete its metabolic process only under low H_2 pressure.

2.4.4 Methanogenesis

The Last stage in anaerobic degradation of biomass is methanogenesis where methane production proceeded by obligatory anaerobic bacteria. The Substance acceptable to methanogen to produce methane would be classified to three category depend on their degradation path way and number of microorganisms that able to handle degradation process [13].

1. CO_2 type: CO_2, $HCOO^-$, CO, all methanogen can reduce specie of this group.
2. Methyl type: CH_3OH, CH_3NH_3, $(CH_3)_2NH^{+2}$, $(CH_3)_3NH^+$,CH_3SH, $(CH_3)_2S$, one type of methanogens can handle dismutation specie of this group.
3. Acetate type: CH_3COO^-, many methanogens can oxide this group.

All methane-forming reactions have different methane yields equation (2.7), equation (2.8) and equation (2.9) show forming reaction from different type of compound. Nevertheless, Most of methane production comes from reduction of CO_2type where it gives 70% of methane yield and only 27-30% from oxidation of acetate type[13].

$$CH_3COOH \rightarrow CH_4 + CO_2 \qquad 2.7$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \qquad 2.8$$

$$CH_3OH + H_2 \rightarrow CH_4 + H_2O \qquad 2.9$$

Methanogens bacteria work in symbiotic with acetones to decrease partial pressure of H_2.Methanogenscan only live with high partial pressure of H_2.Thus it tack produced hydrogen molecules in acetogenesis to complete its metabolic process[13].

2.5 Factors affecting AD process for biogas production

The efficiency of AD is influenced by some critical parameters such as: temperature, pH, Carbon: Nitrogen (C/N) ratio, mixing, OLR, Hydraulic retention time (HRT) , particle size, moisture content and substrate/carbon source.

1. Temperature

The optimal temperature ranges are the mesophilic 30–38 °Cand the thermophilic 44–57 °C [52]. The rate of decomposition and gas production is sensitive to temperature, and in general, the process becomes more rapid at high temperatures. Despite this thermophilic benefit, the digestion process becomes increasingly unstable with rising temperature and requires higher rates of heat inputs[52], and increased toxicity of ammonia[53].Most digesters now operate at mesophilic temperatures, for which good stability and gas production occur. Reactor temperatures between 25 °C and 35 °C are generally the preferred optima to support biological-reaction rates yet provide a more stable treatment. Operating temperature is vital, but stabilizing it is even more important, variations of ±1 °C in a day may force the methane producing organisms [54]. However, the rate of biological activity in the range between 5 °C and35 °C doubles for every 10–15 °C temperature rise. It is important to state that psychrophilic temperature ranges (at ~20 °C) are not suitable for anaerobic digestion. The degradation of long-chain fatty-acids is often rate limiting. If long-chain fatty-acids accumulate, foaming may occur in the reactor and so inhibit process continuity.

2. pH

The substrate's acidity is measured by pH, which is an important parameter affecting the growth of microbes during anaerobic digestion. For optimal performance of the microbes, the pH within the digester should be kept in the range of 6.8 - 8.0. 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 [43]. There are also situations in anaerobic fermentation which can highly affect the pH in the digester. These include high amounts of volatile fatty acids, acetic acid, and carbon dioxide produced by the microbes and ammonia. These factors can have an impact on the pH in the reactor and might inhibit the activity of the microbes[55].

3. Carbon: Nitrogen (C/N) ratio

The concentrations of carbon and nitrogen determine the performance of the anaerobic digestion process, as one or the other limiting factor. For efficient biogas plant operation, the C/N ratio of the input substrate should be kept within the desired range since the nutrient composition has an impact on the optimal growth and activity of micro-organisms[55]. Carbon and nitrogen are the main nutrients for anaerobic bacteria. Whereas carbon constitutes the energy source for the microorganisms, nitrogen serves to enhance microbial growth[56].

In anaerobic digestion, the carbon utilization of micro-organisms is 25-30 times higher than nitrogen. Thus, for optimum functioning microbes usually need 25-30:1 ratio of C to N with the largest part of the carbon being easily degradable. Any deviation from this ration gives a less efficient process[55].

4. Mixing

This is another important operation in achieving optimal anaerobic-digestion[52]. It is desirable to maintain uniformity of (i) substrate concentration, (ii) temperature and (iii) other environmental factors as well as prevent scum formation and solids deposition.

5. OLR

Represents the amount of volatile solids fed into a digester per day under continuous feeding. With increasing OLR, the biogas yield increases to an extent, but the equilibrium and productivity of the digestion process can also be greatly disturbed. Adding a large volume of new material daily may result in changes in the digester's environment and temporarily inhibits bacterial activity during the early stages of fermentation. This bacterial inhibition occurs due to an extremely high OLR leading to higher hydrolysis/ acidogenesis bacterial activity than methanogenesis bacterial activity and thus increases VFA production, which eventually leads to an irreversible acidification. Thereafter, the pH of the digester decreases, and the hydrolysis process is inhibited such that the restricted methanogenesis bacteria are not able to convert as much VFA to methane[57, 58].

6. Hydraulic retention time (HRT)

The average time spent by the biomass inside the digester tank before it comes out. The process of degradation requires at least 10-30 days in mesophilic condition, while in thermophilic environment HRT is usually shorter [59].HRT is correlated to the digester volume and the volume of substrate fed per time unit according to the following

$$HRT = VR / V$$

HRT: hydraulic retention time [days], V_R: digester volume [m³], V: volume of substrate fed per time unit [m³/d]

7. Particle size

The production of biogas is also affected by particle size of the substrate. Too big particle size is problematic for microbes to digest and it can also result in blockage in the digester. Small particle size gives a large surface area for substrate adsorption and thus allows the increased microbial activity followed by increase in the production of gas[55].

8. Moisture content

Usually moisture content have a positive impact on anaerobic digestion process [8].Water is essential to methane fermentation as the nutrients for the microorganisms must dissolve in water before they can be assimilated[60]. The preferable moisture content is higher than 60% [13]. However,L.Márquez-Benavides et.al (2008) show that the methane production rate was higher at moisture content of 70%[61].Water is important agent in bacterial movement, dissolving substance and diffusion of substrates to bacterial sites. high moisture contents may dilute carboxylic acid (such as acetic acid and amino acid) concentrations and provide for more mixing and aid in buffering reactions to reduce the pH inhibition [62].

9. Substrate/carbon source

Almost all type of organic material could be used to anaerobic digestion process[13]. Although, not all used substance give same yield of methane. Main component of biomass used in process could be characterized as carbohydrate, protein, fats (lipids), fibers content (Lignocellulose and lignin) [63]. Degradation rate in hydrolysis step is highly affected by type of those components. Where it could proceeded so quickly in case of certain component such as carbohydrate (within a few hours) or within few days for proteins and lipids or degraded only slowly and incompletely for lignocellulose and lignin [13].

2.6 Bioreactor

The production of biogas can take place with different operating techniques. Two commonly used methods include batch digestion and digestion in a continuous process.

1. **Batch process**

In the batch type digester, the feedstock is filled completely and emptied completely after some retention time. Thus, the daily gas production is build up to the maximum level and then decline after some retention days[64]. Substrate handling is easy with this method though there is a great variation(unsteady)in the production of biogas both in quality and quantity [47].The batch process provides the highest degradation of the substrate material and all degradable materials can be converted to biogas if the retention time is long enough.

2. **Continuous process**

In continuous process, the addition and removal of substrate materials may occur between 1-8 times every day [47]. In this process, the substrate material is pumped regularly into the digester and an equal volume of digested material is displaced and thus the volume in the digester remains constant. With the continuous process the substrate is never fully degraded, the degradation degree can vary between 50-70 %. Continuous feeding of substrate is possible with this kind of process which at last gives much more even production of gas than the batch process. For smaller digester, the feeding of material is often once or twice a day but the larger digester are operated more continuously with feeding intervals of less than one hour [59].

2.7 Case study

Al–jebrini diary Company in Hebron city makes a step forward in the field of biogas production. Construction of biogas plant was a solution for large production of liquid and solid of cow excrete that come from al-jebrini cow ranch with more than 1400 head of cattle. Around 42 ton of solid manure and 82 ton of liquid urine from daily excreta production used as daily feed stock for continuous bioreactor to produce 30000 m^3/day of biogas. The reactor is connected with combined heat and power system (CHP) that producing 370 kW/day. Methane gas represents 60% of produced biogas, and other gas such as $CO_2$and H_2S represent 40%.

Chapter Three

Experimental Work

3.1 Materials

3.1.1 Collection and preparation of substrates

Selection and collection of biomass in experiment was according to classification of biomass in chapter two. Three samples of biomass were obtained from different source. The first sample is cow manure (sample1) which has been considered as representative sample to agricultural source. It was collected from cow farm located in yatta city, while sample 2 as food waste, Fruits and vegetables residues obtained from decentralized fruit and vegetable market, Hebron. Both samples were immediately transferred in a plastic bucket to the laboratory. The third sample is a mixture of cow manure, fruit and vegetable residues as co-digestion sample.

3.1.2 Seeding or Inoculum

To start up a new anaerobic process, it is critical to use an inoculum of microorganisms to commence the fermentation process. The seeding material was a digested sludge from Al-jebrini biogas plant.

3.2 Methods

2.2.1 biomass characteristics

Samples of biomass collected, preserved, and stored in plastic bottles. Refrigerate samples at 4°C up to the time of analysis to minimize microbiological decomposition of solids composition. Characterization of the samples was made within one week after collection. The samples were brought to room temperature before analysis. Cow manure and fruit and vegetable samples were analyzed after four days of preparation. Co-digestion sample were analyzed after one day of preparation. Biomass were characterized including pH by (PCE-228 pH-meter),total solid (TS) that means the weight of sample left after drying the sample at 105 °C for 12 hours compared with the total weight of the sample before drying, and volatile solid (VS) which is the weight loss of the sample weighted before and after burning the sample at 550 °C for 2 hours and repeat cycle of ignition for 30 min until a constant weight is obtained or until weight change is less than 4 %. The final ash left is equal to the sample mineral content.

3.2.1.1 Determination of TS

Crucibles were dried in drying oven at 105°C for 2 hours. Cool the dishes in a desiccator, weigh a pre-dried dish and record this weight (W_1), then mixed the sample and weigh out a certain amount to the nearest 3–4 g into the weighing dish. Place the sample into oven at 105 °C for a minimum of four hours, after that remove the sample from the oven and allow it to cool to room temperature in a desiccator. Weigh the dish containing the oven-dried sample and record this weight (W_2).Then, the TS and moisture content was calculate using equation 3.1

$$\% \, Total\ Solids = \frac{(W_2 - W_1) * 100}{weight\ sample} \qquad 3.1$$

$$\% \, Moisture\ content = 100 - \% \, Total\ Solids \qquad 3.2$$

Where; W_2= (weight dry dish + dry sample) and W_1= weight dry dish

3.2.1.2 Determinationof VS

The sample after being dried was ignited at 550°C for 2 hours, then cool the residue in a desiccator to balance the temperature, weigh the residues and repeat igniting (30 min), cooling, desiccating, weighing until the weight change is less than 4% and record the final weight (W_3) .Then, the VS was calculate using equation 3.3.

$$\% \, Volatile\ solid = \frac{(W_2 - W_3) * 100}{weight\ sample} \qquad 3.3$$

Where; W_2= Weight dried residue + dish and W_3= Weight residue and dish after ignition.

3.2.2 Activated sludge characteristics

The inoculum was not used directly after collection in the batch experiment, it was incubated at refrigerator at 4 °C. The inoculum collected on (2017-03-30) and used for the first and second batch experiment after two days of incubations and for third batch experiment after five days of incubations. Activated sludge characteristics including TS, VS and volatile suspended solid (VSS) were analyzed. VSS value of inoculum determines the amount of inoculum should be added for biomass.

3.2.2.1 Determination of VSS

Crucibles were dried in a drying oven (Daihan LabTech Co., Ltd., korea) at 105 °C for 2 hours then cooled in desiccator. Pre-dried dish and filter paper (1.6 µm) were weighed (W_4).100 ml of diluted sample (0.5mlactivated sludge: 500 ml distillate water) was filtered by vacuum pump and dried in drying oven at 105 °C for at least 1 hour then cooled to room temperature in desiccator. The Filter paper containing the dried residues was heated up in a muffle furnace (Lab Tech.International Ltd., East Sussex, UK) at 550°C for 15minute, then, the VSS value was calculated using equation 3.4

$$VSS\% = \frac{(W_6 - W_5) * 100}{\text{volume of sample}} \qquad 3.4$$

Where; W_6 = weight dry dish + dry sample after 550°c and W_5= Weight residue and dish after ignition.

3.3 Batch experiment

The batch bioreactor system was designed to study the effect of biomass type on the methane yield. Figure (3) shows a schematic sketch of the batch bioreactor system. Plastic Vessel (A) has been filled with the biomass is connected with Vessel (C) containing 16 L of water through flexible pipe (B) in order to collect the biogas by displacing water to Vessel (E)through flexible pipe (D). The sample of biomass is taken from pipe (G) to analyze the characteristic of biomass at different period of time. Furthermore, the sample was extracted from Vessel (C)through pipe (F) in a plastic vessel in order to test the biogas composition.

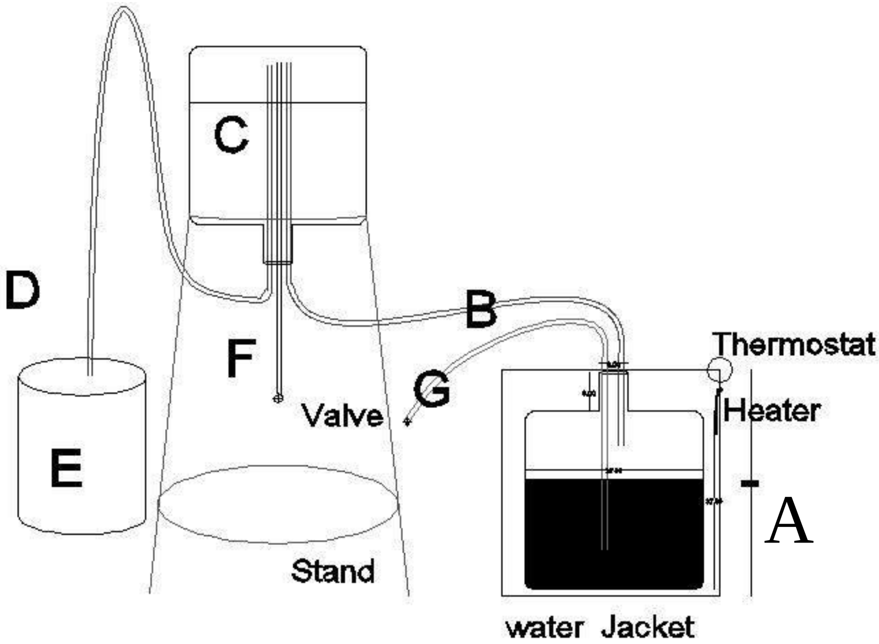

Figure 3: Batch bioreactor system

To produce biogas, an experimental setup has been built of three reactors (R_1, R_2 and R_3). Out of three reactors, R_1 has been filled with cow manure where 7.028 kg of cow manure was mixed with 1kg of water and 1L of activated sludge. Whereas R_2 is filled with 10.5 kg of fruit and vegetable mixture, which is 6.36 kg of marrow, 2.331kg of fennel, 1.088 kg of lettuce and0.765 kg of apple were mixed with 0.381 kg of water and 2L of activated sludge) and R_3 containing 6.661 kg of cow manure and 3.37 kg of fruit and vegetable (marrow and fennel)which form 66.68 %: 33.32 %respectively mixed with0.5 kg of water and 1.5 L of activated sludge. After that closing the reactors with a cork stopper, then the reactors were located ina water jacket at (30 - 40^{o}C)as shown in Figure (4) below.

Figure 4:Batch bioreactor system

3.4 Gas measurement

Gas production was used measuring volume of water displaced, that implies the quantity of gas production. Biogas composition which is CH_4, $CO_2$and O_2analysisby using BIOGAS 5000 Device .

Chapter four

Result and Discussion

This chapter describes the results obtained from anaerobic digestion of substrate (cow manure, fruit and vegetable and co-digestion sample) operated in Mesophilic condition. The experiments were conducted in two parts. The first part about TS, VS and VSS test, the experiment in this part were conducted in two phase the first phase about study of TS and VS value for biomass and the second phase about TS, VS and VSS value for inoculum for anaerobic digestion. The second part about analyze biogas consist ofCH_4, CO_2 and O_2.

4.1 Biomass characteristics

The biomass samples characteristics, including TS,mositure content and VS were tested at starting time as shown in Table (17).

Table 17:pH, TS, mositure content and VS characterization tests of biomass samples at starting time

Sample	pH	TS %	Moisture content %	VS %	VS (% TS)
1	6.38	13.85	86.15	10.9	79
2	6.92	6.2	93.8	5.4	86.49
3	6.38	12.268	87.732	9.6	78.5

Table (17) shows the characteristics of biomass samples collected at starting time.Sample 2 showed the highest pH value, which is in the optimum range (6.8 – 8)[55].Samples 1 and 3have less pH than optimumvalue, but it suitable for anaerobic digestion process..For moisture content characteristic the experimental result shows thatall samples have optimum value of moisture content which around (60-95%)[59].Also the result that obtain from volatile solid test shows high VS value around (79-86.49%) for all samples, that means it contains high organic matter[65].

4.2 Monitoring of samples

Through operation period pH and temperature take various value. Figures (5) and figures (6) show how pH and temperature value varied and the effect of that variation on biogas and methane yield.

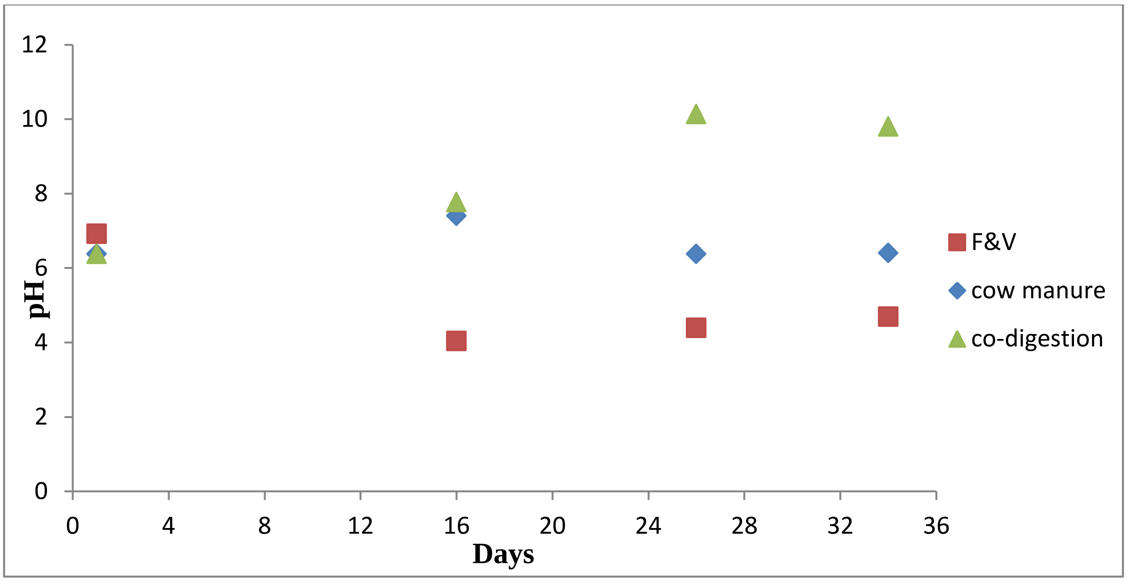

Figure 5: pH for different biomass over operation period

Figure (5)show the flocculation of pH value, where pH value for fruit and vegetable sample was around (6.8 - 4.3), whereas co- digestion sample varied from (6.2 - 10.1), while cow manure sample remain in suitable range(7.4 – 6.38). In fruit and vegetable sample pH decrease at the thirteen day due to rapid acidification and a larger volatile fatty acids production (VFA) which stress and inhibit the activity of methanogen bacteria. At the period between 21 to 25 day pH increase from 4.39 to 5 due to adding 25.83g of limestone mixed with 750 ml of water that have pH 7.37 ,but still less than 6 that means it still under inhibition condition. For co-digestion sample, pH value increases by ammonia accumulation during degradation which inhibit the process and activity of methanogen bacteria.

Temperature of samples is kept in mesophilic range of (30-40 ^{o}C).The average daily temperature was plotted with over a period of 38 days for cow manure , fruit and vegetable and co-digestion samples as shown in figure(6) . It is important to keep a constant temperature during the digestion process, as temperature changes or fluctuations will affect the biogas production negatively. Mesophilic bacteria are sensitive to temperature fluctuation of ±3°C without significant reductions in methane production. Whereas temperature of samples has been flocculated more than ±3°Cthus biogas production negatively affected.

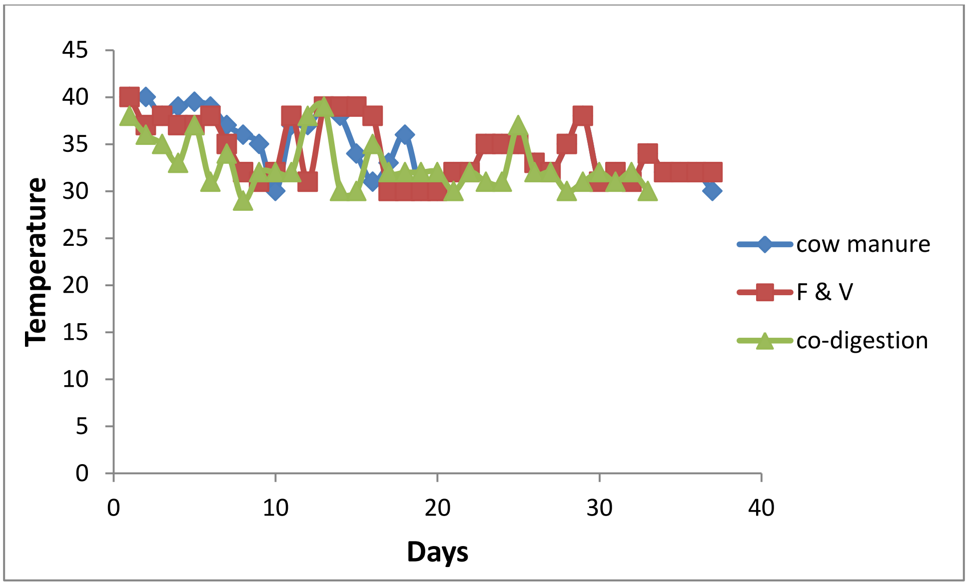

Figure 6:Average daily temperature over a period of 38 days for

4.3 Activated sludge characteristics

Characteristicsof activated sludge sample such as pH, TS, VS and VSS at starting time as shown in Table (18).

Table 18: pH, TS, VS and VSScharacterization tests of activated sludge sample at starting time

Sample	pH	TS %	VS %	VS (%TS)	VSS g/L
Activated sludge	7.5	6.7	4.4	65.34	50

Table (18) shows the characteristics of inoculum samples collected at starting time. Inoculums have pH around 7.5which be used as a buffer capacity that helps to control the change of pH in the system.

Inoculum's buffering capacity help to prevent shock due to the production of acid through the digestion of substrate. Data show that the VS around 65.34 % of TS which considered as high VS value. According to experimental result, VSS value was around the optimum value which is 45 g/L. Under optimum condition where VSS value equal 45 g/L, 200 ml of activated sludge should be added to each liter of samples. The addition of activated sludge was depend on VSS value obtained from the experimental result mentioned before see table (18) where 166 ml of activated sludge were added to each liter of biomass.

4.4 Gas measurement

Table19:Biogas composition for the samples

Sample	CH_4%	CO_2%	O_2%
Cow manure	30%	46.8%	0.1
Fruit and vegetable	4%	30%	5%
Co-digestion	1%	28.8%	12.4%

Table (19) shows yield of biogas composition for the three samples. Methane yield of cow manure sample where lower than the natural percentage which is around 50 to 75%. Decreasing of methane yield caused by break down in reactor body where water leaks from water jacket system to reactor thus total solid of sample decreased that make a huge adverse effect on biogas flow rate. In fruit and vegetable sample methane and carbon dioxide yield is too low comparing with value of other researches as shown in table (12). In this sample the sharp depletion of biogas rate, methane and carbon dioxide yield was due to its high acidity that inhibits methanogenic bacteria. In co-digestion sample oxygen and pH value were the main reasons for inhibition of the anaerobic digestion process.

Recommendations

Anaerobic digestion option proves an attractive option to be used as the technology for treating organic fraction of waste from different sources. This experiment can offer production of biogas as well as the potential investment value of reside by products. Therefore, the new concept should be envisioned that may possibly improve the process for further study. Thus, the following aspect can be taken as the recommendation for future study of such anaerobic digester :

- An attempt on the optimization of batch process for this experiment was not completely achieved since the highest percent methane is only 4% of fruit and vegetable due to acidic ambient which hardly affects methanogenic bacteria so we recommend to add more amount of lime stone cutting powder or add other alkaline compound such as Na_2HCO_3, for co-digestion and cow manure sample the methane yield was not satisfy enough so we recommended to give more attention to technical issue.

- Deficiency of facilities of laboratory and required tools decrease ability to get a daily result. So our recommendation is providing more specialized tools and device that needed for biogas production and monitoring such as wet flow meter, biogas analyzers.

- Due to high sensitivity of bacteria work on producing biogas to temperature change we recommend to use precise digital temperature controller.

- Use different type of heating system like heat exchanger to get the appropriate temperature inside the system.

- Use mixing system to distribute heat and bacteria inside reactors .

- Use different container with different material such as stainless steel or glass.

Conclusion

In this study, effort was made to study the quantity and quality of biogas produced by anaerobic digestion in a batch reactor which was operated under temperature ranged from 30 to 40 °C. The used feed stocks were cow manure, fruit and vegetable and co-digestion samples. Substrates were characterized pH, TS and VS were tested.The biogas composition was analyzed in terms of CH_4, $O_2$and CO_2 .the result of our study concluded that the methane yield and other biogas composition were not satisfying where the highest percent methane is only 4% of fruit and vegetable, 30% of cow manure and 1% of co-digestion

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