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Assessment and Biogas Production from Leftover Food in Main Campus of Ambo University in a Batch Anaerobic Digestion

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Abstract

The objective of this study was to assess and evaluate the biogas yield of food wastes generated from the main campus of Ambo University's student cafeteria in a batch anaerobic digestion. Food waste from pre-processing and leftover from the student cafeteria were collected and measured. Standard techniques were used to analyze the physico-chemical characteristics of the various food wastes, and the barrier solution was used to assess the amount of biogas and methane produced. The daily, weekly, monthly, and yearlygenerated food wastes were: 1,283.02, 8,883.14, 38, 489.06, 204, and 448.78 kg, respectively, and the rate of generation of food waste was 0.37 kg/capita/day. The moisture content ranged from 3.4 ± 0.78% to 93.11 ± 0.30%, total solids from 6.9 ± 0.30% to 96.6 ± 0.72%, VS of TS 82.1 ± 0.59% to 98.1 ± 0.75%, OC from 45.6 ± 0.33% to 54.5 ± 0.02%, and C:N from 33.8% to 20.03 ± 0.3%. The highest average biogas and percentage of methane were measured from FLM (12500 ± 307.16 mL and (81.65 ± 2.58%), respectively, while the lowest average total biogas and percentage of methane were from the FPK (8590.33 ± 260.77 mL and (67.15 ± 2.47%), respectively. The findings of this study revealed that the high quantity of food waste that was readily available at the study site and that could potentially be converted into high quantity and high-quality bio-methane, which could serve two purposes: production of bio-fuels and reducing environmental degradation from the open disposal of food waste.

Keywords: *Anaerobic digestion, Biogas, Food waste, Leftover food, Methane, Pre-possessing, Open disposal.*

1. Introduction

Energy is one of the most basic elements of the universe derived from both renewable and non-renewable sources. According to Owusu and Sarkodie [1], the demand for energy and its related services to support human social and economic development has sporadically been on the rise as a result of the widespread usage of fossil fuels (oil, gas, and coal) as a primary energy source. Research into renewable energy sources from biomass is being driven by the world's irrational use of fossil fuels and the effects of greenhouse gases (GHGs) on the environment [2]. The key to solving the climate disaster is switching from fossil fuels, which are now sources of the majority of emissions, to renewable energy [3]. Renewable energy comes from natural sources that replace themselves more quickly than they are used up. Bio-energy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung, and other manures for heat and power production, and crops for liquid bio-fuels. Most biomass is used in rural areas for cooking, lighting, and heating, generally by poorer populations in developing countries. Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams [4].

BUMBIERE *et al*. [5] compared and ranked eight different substrates for biogas production considering their economic feasibility, substrate efficiency, and environmental aspects including cattle manure, pig manure, poultry manure, straw, wood, maize silage waste, and sewage sludge, and they indicated that pig manure is the most suitable raw material for biogas production while poultry manure was ranked second, with little difference in value from pig manure. Gao *et al*. [6] evaluated anaerobic co-digestion of spent mushroom substrate with different agricultural wastes such as livestock, chicken, dairy, and pig manure, and they found that combing yellow back fungus spent mushroom substrate with chicken manure yielded a slightly higher cumulative methane yield when compared with the combination of dairy manure and pig manure. Herout, *et al*. [7] reported that maize silage with liquid beef manure in the ratio of 40:60 produced biogas with a high content of methane. These authors indicated that at this concentration of input of raw material, the formation of undesirable high concentrations of hydrogen sulphide occurs as well, while the addition of other components of plant biomass like grass haylage and rye grain minimized the formation of hydrogen sulphid.

Nwokolo *et al*. [8] emphasized that the biogas produced through anaerobic digestion varies in composition, but it consists mainly of carbon dioxide, methane together with a low quantity of trace gases. The variation in biogas composition are dependent on some factors namely the substrate type being digested, pH, operating temperature, organic loading rate, hydraulic retention time and digester design. However, the type of substrate used is of greater interest due to the direct dependency of microorganism activities on the nutritional composition of the substrate.

However, food wastes from various sources could also be used for the production of bio-energy. Food is wasted across the whole food supply chain including at harvest, post-harvest, processing, distribution, and at the consumer level [9]. Up to one-third nearing to 1300 million tons of food that are with intent grown for human use each year are wasted and depending on the eating patterns of communities in different nations, food waste contains between 18 and 31 % total solids and between 70 and 80% water (10, 11).

Land filling can be used for disposal of food wastes; however, is pricy, takes up many lands, and if not properly managed, can have a detrimental influence on the environment due to the generation of leachate, methane, and carbon dioxide as well as other annoyances like flies, odor, and vermin like birds and rats. Along with the emission of methane, a powerful greenhouse gas with an immediate global warming potential 84 times greater than that of carbon dioxide, leachate may also damage soil and underground water [10, 11]. Hence, employing food waste as a possible source for the production of sustainable fuels through anaerobic digestion (AD) will end this waste stream's lifecycle responsibly, and so directly support and promote the idea of the circular economy through open-loop recycling [12, 13, 14].

Biogas is one of the most promising alternative energy sources that is produced from biodegradable organic wastes like food waste through anaerobic digestion (AD) [15, 16]. It serves as a high-energy renewable fuel, which could be used as a substitute for fossil fuels for various purposes such as cooking, heating, transportation, and electricity [17, 18]. It also indicated that the AD approach is one of the most eco-friendly and promising solutions for food waste management. Farther more, one of the greatest challenges facing societies now and will continue in the future is the reduction of GHG emitted from inappropriate ways to dispose of food waste and thus preventing climate change [19]. Nowadays, different food wastes, both pre-processed food wastes and leftover foods, are the most significant portions of solid organic waste generated from the students' cafeteria of the main campus of Ambo University and the food waste disposal method in this campus is open dumping. This would be conducive to the multiplying of vectors and cause an unhealthy environment for the students, cafeteria workers, and society nearby the University. In addition, it contaminates soil and groundwater as well as surface water through runoff or leachate. Thus to minimize the effect of open disposal of food waste from the student cafeteria of the main campus of Ambo University, the conversion of these food wastes into some sort of energy is very important. However, there is no study conducted to evaluate biogas yield from different food wastes generated from students' cafeterias of the main campus of Ambo University. Additionally, there is limited biogas research in the studied area from pre-processed and leftover food. Therefore, by converting food waste into energy that can be used for a variety of purposes, this will create new opportunities for handling food wastes. Therefore, the general objective of this study is to assess and evaluate biogas yield from different food wastes from the students' cafeterias of the main campus of Ambo University.

2. Materials and methods

2.1. Description of studied area

The study was conducted in the Ambo University main campus. Geographically, Ambo University was located in Ambo town, in West Shoa Zone, Oromia Regional State, central Ethiopia lying between $8^0$56'30'' - $8^0$59'30''N latitude and $37^0$47'30'' - $37^0$55'15''E longitude. The altitude of the studied area ranges between 2000 meters to 2400 meters and an average altitude of 2200 meters above sea level. Ambo is characterized by warm temperate; its weather is locally called 'Bada-dare'. The temperature ranges from 15 ^{0}C –

29 ^{o}C with an average annual temperature of 22 ^{0}C. The area gets a mean annual rainfall ranging from 800-1000 mm with an average of 900 mm [20].

2.2. Assessment of food wastes

Sampling technique: For assessments and evaluation of biogas yield of food waste, the main campus of Ambo University was purposefully selected as a studied site. In this study, pre-processing and leftover food sources, sampling sites, and measurement points were identified through visual assessment and field observation. Several data collection methods were employed: on-site measurement of food waste, observation, and experience sharing. For evaluation of the amount of food wastes generated in the student cafeteria of the main campus of Ambo University, both the pre-possessing (before meal preparation) and leftover food (remaining food collected after meal) were collected in synthetic sacs or "Madaberiya," by daily laborers and measured on balance and the amount was registered. From the three student cafeterias of the main campus of the Ambo University, the one serving for about 680 students was selected for quantification of the food left over, while the total student of the campus at the time of the study was 3,469 and the total and rate food waste generation per capita per day was estimated from this cafeteria by collecting and measuring 100% leftover food [21].

2.3. Determination of physico-chemical properties of food waste

Moisture content: The moisture content of the food waste samples was determined using the oven–drying method. 5 g of each food waste sample was transferred to a pre-weighed crucible, and the weight of food waste together with crucible was recorded. Pre–weighed samples were dried in the drying oven at 105 ˚C for 24 hours. The crucibles with dried samples were cooled in desiccators, and weighed using an electronic weighing balance. Moisture content was calculated using equation 1 [22].

$$\%\,\mathbf{MC}=\frac{\mathbf{W-D}}{\mathbf{W}}*\mathbf{100} \tag{1}$$

where W is weight of food waste before drying; D is weight of food waste after drying.

Total solids (%TS): In order to determine the total solids of the food waste, each sample of the food waste was placed on the crucible and put in a drying oven at 105 ˚C to evaporate for 24 h.

ours. After 24 hours, the crucible was taken out from the drying oven, cooled in desiccators, and weighed using an electronic balance. The percentage of %TS was calculated using equation (2) [22].

$$\%TS=\frac{A---B}{C} \tag{2}$$

wher, A is weight of dried residue + crucible (g); B is weight of crucible (g); and C is weight of wet sample + crucible (g)

Determination of volatile solids (%VS)

Volatile Solids (%VS): In order to determine the volatile solids (%TS), the samples were dried in oven- at 105 ºC for 24 hours and cooled in desiccators, weighed, and recorded. The residue of each sample was ignited to constant weight in the muffle furnace at 550 ˚C for 6 hours. Then the samples were removed from the muffle furnace cooled in a desiccators, and weighed using an electronic balance. The percentage of total volatile solids (%VS) was determined using equation (3) [23].

$$\%VS=TS-\left(\frac{WA}{Ww}\right)\times 100 \tag{3}$$

where WA is weight of ash (g); Ww is the weight of wet sample (g).

Total ash (%TA): A gram of each sample was weighed and then transferred into the crucibles. The crucibles were placed in the muffle furnace and heated first over a low flame till all the material was completely char followed by heating in the muffle furnace for about 6 hours at 550 ºC. They were then cooled in desiccators and weighed. To ensure the completion of ashing, the crucibles were then heated in the muffle furnace for 1 hour then cooled and weighed. Then, the total ash of the sample of food waste was calculated using equation (4) [24].

$$\%\mathbf{TA}=\frac{\mathbf{WA}}{\mathbf{WS}}\times\mathbf{100} \tag{4}$$

where TA is total ash of g/100g sample; WA is the weight of ash (g); WS is the weight of sample taken (g).

Organic carbon (%OC): The oven-dried samples were analyzed for the initial carbon concentration using the ash method. According to [25], for most biological materials, the carbon content is between 45 to 60% of the VS fraction. Assuming 55% VS of biological materials, equation 5 was used to calculate the carbon content.

$$\%\mathbf{C}=\frac{\%\mathbf{VS}}{\mathbf{1.8}} \tag{5}$$

where %VS = 100-% ash; 1.8 = an average carbon content for most of the biological materials.

Total nitrogen content (%TN): The total nitrogen content of dried food waste samples was determined using the Kjeldahl method. Digestion, distillation, and titration are the three main steps involved in this method. The total nitrogen tool including the Kjeldahl digester unit (Gerhardt, kjeldatherm) was used to digest the samples [26]. The result was calculated by using equation (6).

$$\%\ \text{TOTAL NITROGEN (TN)} = \frac{(A-B)*N*0.014*100*mcf}{S} \quad (6)$$

where A is the amount of H_2SO_4 consumed (mL) to an end point of the titration, B is the amount of H_2SO_4 required (mL) for titration of blank, N is the normality of H_2SO_4 (0.1 N) in milliliter, S is the sample weight on dry matter basis in grams, 0.014 is the molecular weight of nitrogen in grams, and mcf is the moisture correction factor.

Carbon:nitrogen ratio: The C:N ratio was calculated by using equation (7) below.

$$\frac{\%\mathbf{C}}{\%\mathbf{N}} = \mathbf{C:N} \quad (7)$$

where %C is the percentage of the initial carbon content of experimental samples determined by using the ash method.

2.4. Inoculums preparation and experimental setup

Inoculums preparation: The inoculum was prepared from a (1:1 v/v) fresh cow dung and tap water in 100 L capacity packet. A water bath (Electro thermal constant temperature, model SY-1L.2H) was used to keep the temperature at mesophilic condition at 38 ± 1 ˚C. The water pump (type ONDINA 50M) was used to pump and circulate the hot water from the water bath to the digester holding the inoculum through the pipe connected figure 1.

Preparation of substrate for anaerobic digestion: For evaluation of biogas yield, eight different food wastes were used: two from the pre-processing food, three from breakfast leftover foods, and three from the dinner and lunch leftover food. Fresh weight of pre-processed food wastes (pre-processed Kincke (FPK) and potato peels (FPP) was dried by removing the moisture. A coffee grinding mill was used to reduce the size of FPK and FPP. The leftover food samples were homogenized before use.

Experimental design: Anaerobic batch digesters (flasks) with a total volume of 500 mL and a working volume of 400 mL were used as digesters (bioreactors) in this study. The butyl rubber (rubber borers) for fitting to each digester and the T-tube plastering materials with plastic gas bags were used to collect the biogas produced from the digester figure 1. The digesters were operated at a mesophilic temperature of (38 ± 1) ℃ by circulating hot water from the water bath to digester for 40 days. A digester was loaded with 25 g of each food waste based on the %VS of the substrates and inoculum.

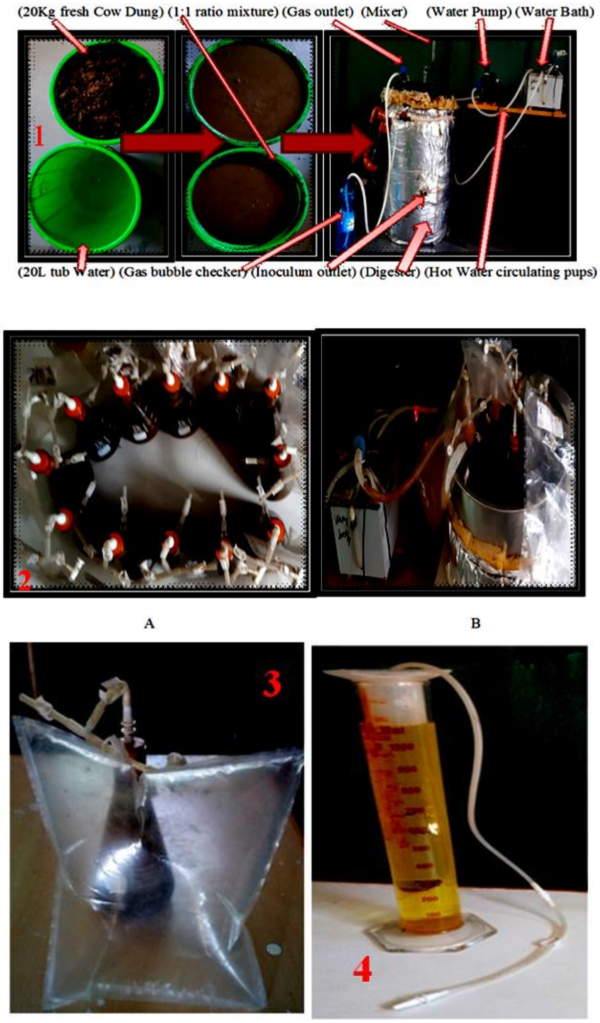

Figure 1. Experimental setup of the anaerobic digestion in this study: 1) inoculums development; 2(A) the arrangement of the anaerobic digestion; 2(B) fermentation processes by circulation of hot water for temperature maintained, 3) produced biogas in the gas bag, 4) barrier solution for the gas measurement through fluid displacement.

Measurement of gas volume and methane percentage

Biogas collection and measurement: Biogas was collected in gas bags (Tedlar gas bag) with a volume of 2.5 liters positioned outside of reactor and connected with plastic pipes. Biogas was measured regularly during the fermentation period every other day. Biogas volume measurement was done by a gas suction graduated cylinder with

1000 mL volume containing barrier solutions (solution prepared from concentrated NaCl and citric acid to prevent dissociation of gases) figure 2 [27].

Determination of percentage of methane: The percentage of the methane content of each sample was measured regularly during the fermentation period every other day. A syringe with a 5 mL volume was used to take biogas from a graduated cylinder containing barrier solutions and transfer it to the 50 mL of 7M NaOH to determine the biogas composition (CH_4 and CO_2) of each sample. Finally, the percentage of methane was calculated, and the flammability of the methane was checked [27].

2.5. Statistical analysis

To determine the effect of the different food wastes on biogas yield and %CH_4, the data collected was subjected to statistical analysis using the Statistical Analysis System software (SPSS v. 25), and one-way analysis of variance (ANOVA). ANOVA was used to compare the results of the mean values of the biogas yield and percentage of methane content generated from each sample mL/g VS every other day as well as accumulated biogas, methane, and carbon dioxide yield generated through 40 days at a 95% confidence level. The descriptive result helped to conclude which type of food waste enhanced biogas yield and percent of methane content under the anaerobic condition at a 95% confidence level.

3. Results

3.1. Assessment and quantification of food wastes

In this study, the two food wastes produced from the food pre-processing (before meal preparation) of the main campus of Ambo University were onion peels (OP) and flour of kinche (FPK), while Kinche (FBK), rice (FBR), and firfir (FBF) from breakfast were the major leftover food that were collected and evaluated, and Injera with lentil stew (FLL), Injera with meat stew (FLM), and Injera with pea stew (FDP) from lunch and dinner. All the food wastes generated in the student cafeteria of the main campus of the Ambo University deposited in open environments. For this, the leftover food and pre-processed food Wastes were collected in synthetic sacs, or "Madaberiya," by daily laborers and transported to the inner side of the Huluka river bank in the main campus of the Ambo University by pickup truck (Figure 2).

In order to estimate the amount of food wastes generated (total or per head/student) in the main campus of the Ambo University the food wastes were collected and measured. Table 1 below displays the estimated food waste generated from the student cafeteria of the main campus of Ambo University. For three consecutive weeks, food wastes from the pre-processing site, leftover food from breakfast, lunch, and dinner were measured in order to determine the total daily food waste produced from the Ambo University main campus student cafeteria. As a result, the daily, weekly, monthly and yearly estimated food wastes in kg (1,283.03, 8,883.14, 38,499.06, and 204,448.78 were recorded, respectively, and the per capita food waste generated for the each student was 0.37 kg/capita/day.

Figure 2. Overview of the open damping site of the food waste in the main campus of Ambo University.

Table 1. The total food wastes estimated from students cafeteria of main campus of Ambo University in Kg.

Sample code	**Periods of food waste measurements**			
	Day	**Week**	**Month**	**Year**
FPK	13.50	94.50	405.00	4440.19
OP	99.29	695.00	2978.70	25194.64
FBK	119.17	834.18	3575.04	17698.93
FBR	67.26	470.82	2017.80	9982.69
FBF	65.80	460.59	1973.94	8681.23
FLM	210.55	1473.88	6316.50	40035.12
FLL	269.77	1888.41	8093.19	31185.58
FDP	437.96	3065.74	13138.89	68230.40
Total	**1,283.30**	**8883.14**	**38,499.06**	**204,448.78**

3.2. Determination of physico-chemical properties of different food wastes

The results of physico-chemical properties of the different food wastes are shown in table 2 as mean and standard deviations. The highest moisture content was recorded for inoculum (93.11 ± 0.3%) and the least was that of the FPK (3.4 ± 0.72); the moisture content of the remaining samples was ranged from 59.3 ± 0.56 to 67.4 ± 0.42 for FBK and FLM, respectively. The highest total solid was recorded from FPK and PP which was ranged from 96.6 ± 0.72 to 96.18 ± 0.34, respectively, while the least was recorded from the inoculum 6.9 ± 0.3, and the rest of the food waste showed intermediate total solid between the highest and the lowest (Table 2). The highest ash content was measured for FPK 3.66 ± 0.17 followed by FPP, 3.1 ± 0.17, and the remaining food leftover were showed ash content ranged from 1.28 ± 0.20 FBR to 0.77 ± 0.01 for FBK. The highest Total VS was from FPP, 93.1 ± 0.4 followed by FPK 92.9 ± 0.75 and lowest from inoculum 5.7 ± 0.28. VS/TS different food wastes were ranged from FBK 98.1 ± 0.04 to 82.1 ± 0.59 for the inoculum. Highest organic carbon content was ranged from 54.5 ± 0.02 to 45.6 ± 0.33. The total nitrogen was ranged from 2.67 ± 0.06 to 1.35 ± 0.04. The C:N ratio was ranged from 33.8 ± 0.83 to 20.03 ± 0.45.

Table 2. Physico-chemical properties of different food wastes.

Sample code	% MC	%TS	%Ash	%VS	%VS of TS	%OC	%TN	C:N ratio
FPK	3.4±0.72	96.6±0.72	3.66±0.17	92.9±0.75	96.2±0.18	53.4±0.10	2.67±0.06	20.03±0.45
FPP	3.8±0.34	96.18±0.34	3.1±0.17	93.1±0.40	96.8±0.18	53.8±0.10	2.56±0.06	20.77±0.51
FBK	59.3±0.56	40.7±0.56	0.77±0.01	39.9±0.56	98.1±0.04	54.5±0.02	1.96±0.01	27.81±0.14
FBR	65.5±7.73	34.5±7.73	1.28±0.20	33.2±7.90	96.1±1.39	53.4±0.77	1.97±0.01	27.12±0.48
FBF	64.5±1.67	35.5±1.67	1.22±0.15	34.2±1.80	96.5±0.57	53.6±0.32	1.98±0.01	27.07±0.16
FLL	64.4±6.99	35.6±6.99	0.86±0.10	34.8±7.10	97.5±0.77	54.2±0.43	1.89±0.01	28.67±0.35
FLM	67.4±4.42	32.6±4.42	0.52±0.10	32.1±4.39	98.4±0.35	54.7±0.19	1.87±0.02	29.18±0.41
FDP	66.4±0.46	33.4±0.46	0.93±0.26	32.5±0.30	97.2±0.75	53.8±0.42	1.98±0.02	27.17±0.27
INOC	93.11±0.30	6.9±0.30	1.23±0.01	5.7±0.29	82.1±0.59	45.6±0.33	1.35±0.04	33.8±0.83

3.3. Evaluation of biogas and methane yield

The different food samples significantly affected quantity of biogas yield (P ≤ 0.05); the Duncan's homogeneous multiple range tests showed that (FPK, FPP), (FBR, FBF), and (FDP, FLL, and FBK) were within the same homogeneous group. Figure 3 below shows the volume of biogas produced from each samples in every other day within the retention of 40 days and the highest biogas yield was recorded from the FLM (500 ± 12.29) mL/g VS, while the lowest biogas yield was recorded from the FPK (343.61 ± 10.43) mL/g VS. The remaining treatments showed intermediate results between the highest and lowest biogas yield.

The samples taken from pre-processing (FPK and FPP) were not produced biogas until the 6 days of incubation time and the average biogas of 106 mL and 195 mL, respectively, and then slowly increased to 446 mL and 500 mL, respectively, on day 12 of the retention period. Production of high biogas yield from FPK and FPP started on day 14 by producing average 800 mL and 850 mL of biogas yield, respectively, and then continuously increases until it reached the peak on day 18 by producing average 1190 mL and 1203 mL of biogas yield, respectively. On other hand from leftover foods FBK, FBR, FBF, FLL, FLM, and FDP biogas production started on day 2 of the retention period by producing 320 mL, 202 mL, 280 mL, 303 mL, 380 mL, and 313 mL of average biogas yield, respectively.

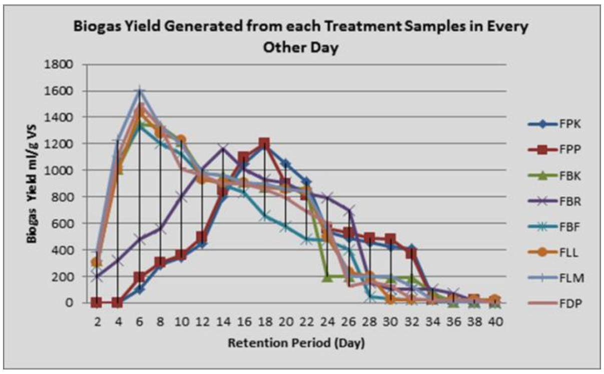

Figure 3. Biogas yield from the different food wastes measured in every other day during the retentions time.

The total highest accumulated biogas yield and methane yield were recorded from the FLM (12500 ± 307.16 mL and 10211.16 ± 564.57 mL), respectively, while the lowest accumulated biogas yield and methane yield were recorded from the FPK (8590.33 ± 260.77 mL and 5771.34 ± 365.99 mL), respectively. All the remaining food samples were shown in the intermediate results between the highest and lowest (Figure 4).

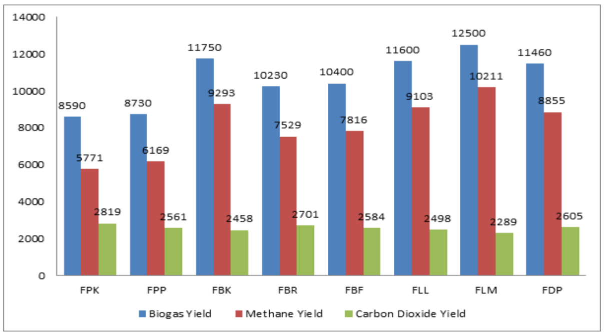

Figure 4. Accumulated biogas, percentage of methane, and CO_2 throughout the anaerobic digestions.

The methane contents of biogas were produced from the different food wastes.

The methane content of the biogas produced from the different food samples was showed statistically significant ($P \leq 0.05$) variations, and the highest percentage of methane was produced from FLM (81.65 ± 2.58%), while the lowest percentage of methane was recorded from the FPK (67.15 ± 2.47%); the remaining food wastes evaluated were shown in the intermediate results between the highest the lowest methane percentage (Table 3).

Table 3. Percentage of methane and CO_2 analyzed from the biogas produced.

Sample Code	Percent of Methane	Percent of Carbon dioxide
FPK	67.15±2.47	32.85±2.47
FPP	70.6±3.21	29.40±3.21
FBK	79.01±2.58	20.99±2.58
FBR	73.53±3.33	26.47±3.33
FBF	75.15±2.62	24.85±2.62
FLL	78.41±2.59	21.59±2.59
FLM	81.65±2.58	18.35±2.58
FDP	77.25±1.59	22.75±1.59

4. Discussion

This study revealed that large amount of food waste generation from the student cafeteria of the main campus of Ambo University and the total estimated food wastes in kg (1,283.03, 8,883.14, 38,499.06, and 204,448.78 were recorded, respectively, and the per capita food waste for the each student was 0.37 kg/capita/day. The disposal method of this food wastes was open dumping which may encourage the growth of vectors and results in malodorous environment. The finding of this study was corroborates with the results reported in the literature. According to Helelo *et al.* [28], the solid waste generated from Hawassa University main campus was dumped at the back site of its compound using handcart and daily laborers, and the waste generation rate of Hawassa University main campus was 0.32 Kg/capita/day and 0.33 Kg/capita/day for the other three campuses each. The food waste generated from the main campus of Ambo University seems greater than the amount reported for the other institutes that may be attributed to differences in types of food and method of preparation and the material used for its preparations.

The moisture content of the different food wastes was ranged from 93.11 ± 0.3% to 3.4 ± 0.72. the result of this investigation was greater than the proposed moisture content 75% of food waste [29, 30]; the authors also stated that water content in food waste varies widely depending on the food source, and thus measuring the moisture content of each food waste sample is crucial when calculating the total quantities produced and the nutrient content in each sample. In this research work, the total solid was ranged from 96.6 ± 0.72 to 96.18 ± 0.34 for FPK and PP, respectively. Massreshaw [31] reported the total solid content of fruit vegetable waste 78.85%, which was by far less than the total solids analyzed in all of the food waste analyzed in this study, that may be due to the differences in the nature of samples and their sources. The ash content of the different food samples was ranged from 3.66 ± 0.17 to 0.77 ± 0.01, which was by far smaller than the results stated by [31]; 11.11% of this may be due to high amount of biodegradable organic matter in the food waste than the fruit vegetable waste. In this research work, the total VS were 93.1 ± 0.4 to 5.7 ± 0.28 for FPP and FBR, respectively. This show similarity with [31] reported VS for TS, 90.602%, in fruit vegetable waste, and greater than the one stated by Steffen, *et al.* [32], which was 75-80%. In this investigation, the organic carbon content was ranged from 54.5 ± 0.02 to 45.6 ± 0.33, which was within the recommended %OC which was between 45 and 60% [25]. In this research work, the total nitrogen was ranged from 2.67 ± 0.06 to 1.35 ± 0.04, and this parameter was not reported for the substrate of anaerobic digestion for the biogas production. In this study, the C:N ratio was ranged from 33.8 ± 0.83 to 20.03 ±0.45. Paritosh *et al.* [33] argued that C:N ratio found in line 20:1 and 35:1 were normally mentioned as suitable range to keep the AD in a stable condition, while the recommended %OC is between 45 and 60% [25].

In this investigation, the volume of biogas produced from each samples was measured in every other day throughout the retention period of 40 days and the highest biogas yield was recorded from the FLM (500 ± 12.29) mL/g VS, while the lowest was recorded from the FPK (343.61 ± 10.43) mL/g VS. The remaining treatments showed intermediate results between the highest and lowest biogas yield. Most of the reported results on the biogas yield from different substrate was indicated the final or the accumulated biogas for the entire retantion period. In this study, the highest total accumulated biogas yield and methane yield were recorded from the FLM (12500 ± 307.16 mL and 10211.16 ± 564.57 mL), respectively, while the lowest accumulated biogas and methane yield were recorded from the FPK (8590.33 ± 260.77 mL and 5771.34 ± 365.99 mL), respectively. The results of this study was in line with the results reported by different authors [31] argued that that of cow dung to fruit vegetable waste T2 (1:3) gave the highest (7552.67 mL) in 13 weeks digestion, while (T5) fruit vegetable waste alone produced lowest of the five treatment 2652.84 mL of biogas production. The maximum accumulation of biogas seen in this study may be related to the food waste's nutrient content and other physicochemical characteristics, which were found to be conducive to the growth of methanogenic bacteria and production of the biogas. In another report, Al-Wahaibi *et al*. [30] evaluated date fruit, rice waste, legume beans, and the mixed food waste and reported that the accumulated biogas, at day 21, the highest gas production values from the rice waste and mixed food waste samples were of~1600 and 1550 mL/1 g DM, respectively. This result is also smaller than the results recorded in this study. In this investigation, the highest percentage of methane was produced from FLM (81.65 ± 2.58%), while the lowest percentage of methane was recorded from the FPK (67.15 ± 2.47. The results of the methane yield observed in this research was in line with [31]. The other treatments for methane production percentage T1 (cow dung alone, T2 (1:3) cow dung to fruit vegetable waste, and T4 (4:1) cow dung fruit vegetable waste produced 78.354%, 67.942%, and 74.0962%, respectively, throughout anaerobic digestion.

5. Conclusion

Biogas technology has the potential to significantly improve both the quality of life in rural and urban areas by reducing the need for essential fuels, enhancing hygiene and health, and mitigating a number of issues associated to environmental imbalance. Although anaerobic digestion is a realistic and practical method for converting food waste to biogas quick acidification of food wastes in anaerobic digestion causes the process to run at a lower organic loading rate. In this study, the various food wastes assessed exhibited favorable physico-chemical characteristics, leading to significant biogas accumulation and the greatest percentage of methane generation, up to 81%. In this study, the different food wastes evaluated showed good properties of physico-chemical parameter and resulted high accumulation of the biogas and highest percentage of methane yield up to 81%.

As a result, the extensive production of biogas from the leftover food from Ambo University's main campus may help to preserve the environment, provide stabilized slurries that may be used as soil coordinators, and generate income.

6. References

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