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# Reporting Biogas Data from Various Feedstock

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**Abstract**

The knowledge of nutrient composition of specific substrate(s) for anaerobic digestion for the production of biogas can provide first-hand information on the possible outcome of digesting such feedstock. It will also help in planning the construction of large-scale biogas plants based on the awareness of the substrates output quantity of biodegradation products. This paper aims to present feedstock information, yield of the bioprocess and bioenergy capacity of products from anaerobic digestion for comparison, studies and analysis.

***Keywords:*** Biogas yield; Bioenergy; Electricity generation; Biogas potential; Feedstock Type.

## 1. Introduction

Biogas is produced conventionally using fixed-domed digester, tubular or balloon bioreactor, floating drum reactor and fiberglass biodigester which is initiated by injecting organic waste feedstock to be degraded by anaerobic bacteria at suitable temperature and pH. Biogas is a colorless gas composed of majority of methane ($CH_4$) and carbon dioxide ($CO_2$) with small concentrations of other gases. Usually, substrates used for anaerobic digestion falls under either of agricultural, industrial or municipal waste. Often times in the literature, characteristics and biogas potential of single or multiple feedstock that had undergone anaerobic process are reported. Due to the fact that anaerobic digestion for biogas production is carried out at various conditions that gives desirable amount of product, literature information or results documented by researchers are most times insufficient. Despite the multitude papers and publications on diverse feedstock, work on anaerobic digestion for biogas production is still encouraged. Production of biogas can be done utilizing lots of organic waste feedstock as shown in Fig. 1. Few among these substrates are captured by this paper in Table 1, 3-5 and 8-9. It is a random data on the amount of heat, electricity, biofertilizer and biogas/biomethane potential of some selected feedstock based on known amount of substrate sample taken for digestion and percent dry matter, volatile solids and moisture content present.

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The tables reported mostly, manures, energy crops and crop waste excluding wastewater from industries such as textile, beverage, dairy, pharmaceutical and sugar industries. Chicken and bovine manure are among the highest most explored manures for anaerobic digestion. Table 2, 6 and 7 therefore singled out chicken manure for data fitting with model equations from Polymath regression software. Other poultry birds like duck and turkey are hardly given attention. Abdallah and his colleagues (2018)'s work on cow manure (a member of the cattle group – bovine) gives a methane yield in the range of 148-216 L $CH_4$/kgVS while that of Mohammed and his colleagues (2019) from paunch manure produces fairly considerable litres of biogas for the period of 49 days it was experimented. Though, a horse is capable of producing 50 kg of dung per day [1] from horses used for sports, work and leisure [2], it is less utilized for biogas production.


**Figure 1:** Some Feedstock for Anaerobic Digestion

The selection of organic substrate(s) for anaerobic digestion often depends on several factors which includes availability, nutrient content and quantity. Oat is among the most nutrient-dense foods with the benefit of controlling blood sugar, lowering cholesterol level, relieving constipation, reducing the risk of asthma in infants, skin care for reduction of inflammation, cleansing, moisturizing and soothing dry itchy skin, and the production of biogas. The challenges of the use of oat is that, it is a scarce material or feedstock which cannot serve a large scale production of biogas.

**2. Biogas Feedstock and Biogas to Bioenergy Data**

The product of anaerobic digestion of organic substrates are biogas and biofertilizer. Biofertilizer are used in farms for improved growth and bumper harvest of planted crops as alternative to chemical fertilizer. Biogas then goes to heat and electricity generation after been clean or refined via different types of treatment method to remove impurities and to make them a suitable substitute to natural gas. The feedstock of anaerobic digestion are often characterized to determine the carbon content, percent total solids, volatile solid percentage, ash content, nitrogen level, moisture content among others to know the required level that will effectively produce the desired amount of biogas from the channeled feedstock. Sometimes available literature values of these compositions might be a reasonable guess to carryout anaerobic digestion of a particular feedstock.

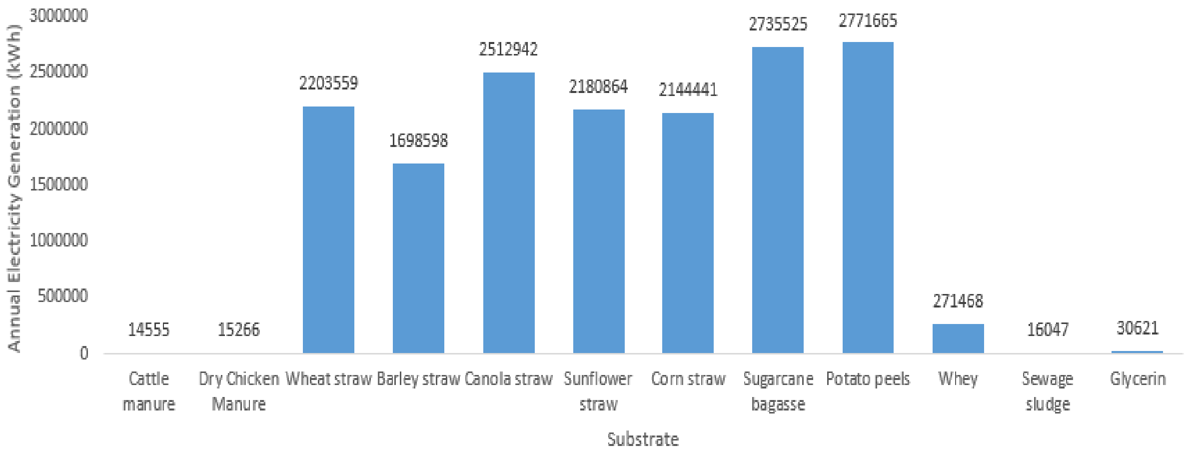


**Figure 2:** Substrate(s) Potential of Electricity Generation [3]

Operators of biogas plants serving the purpose of generating electricity would be interested in feedstock amount and compositions that is capable of generating high kilo-watt-hour of power if used as substrate (see Fig. 2). Different records of power output of some feedstock are presented in this paper. The largest generators of electricity from biogas is Europe followed by Asia. Biogas is still least exploited in Africa despite shortages in the generation of electricity in the continent. It will be very useful for rural areas in Africa to have biogas plants to meet their energy needs as majority of farmers there still depend on firewood. In the face of increased waste accumulation and the challenges with industrial scale production of biogas, many countries haven't develop interest to generate power from biogas, but are however, shifting to natural gas as alternative source of fuel [4]. As transportation fuel, biogas is widely used in Indian commercial buses to provide a cheaper means of urban transport to the populace. Table 1 presents heat, biofertilizer and biogas output of four (4) selected manures:

**Table 1:** Annual Biogas Output Information from Manures [1]

| Substrate | Amount (tons/yr) | Bio Natural Gas ($m^3$/yr) | Electricity (kWh/yr) | Heat (kWh/yr) | Organic Fertilizer (tons/yr) |
|---|---|---|---|---|---|
| Chicken manure | 7000 | 462000 | 1755600 | 2079000 | 6860 |
| Cattle manure (straw bedding) | 3500 | 164500 | 625100 | 740250 | 3430 |
| Horse manure (straw bedding) | 500 | 21500 | 81700 | 96750 | 490 |
| Turkey manure (straw bedding) | 2900 | 252300 | 958740 | 1135350 | 2842 |

Chicken manure is one of the most widely used substrate channeled for the production of biogas/biofertilizer. Renergon (2021) reported the amount per year of biogas that would be generated based on different weight of chicken manure. Using Polymath 6.10 Educational Release to perform polynomial regression of the chicken manure data in Table 2 gives equation 1:

$$BNG = a_0 + a_1 AF + a_2 AF^2 \quad (1)$$

where, $BNG =$ bio natural gas generated per year; $a_0 = 3.262 \times 10^{-9}$, $a_1 = 66$, $a_2 = 3.413 \times 10^{-17}$ are dimensionless constant parameters; and $AF =$ amount of feedstock (or chicken manure) fed in the anaerobic digester annually.

**Table 2:** Biogas Yield based on Amount of Chicken Manure Sample [1]

| Bio Natural Gas ($m^3$/yr) | Amount of feedstock (tons/yr) |
|---|---|
| 264000 | 4000 |
| 363000 | 5500 |
| 719400 | 10900 |
| 422400 | 6400 |
| 178200 | 2700 |
| 950400 | 14400 |
| 752400 | 11400 |
| 844800 | 12800 |
| 204600 | 3100 |
| 125400 | 1900 |
| 92400 | 1400 |
| 547800 | 8300 |

Equation 1 is only valid for range of values of AF from 1400-14400 tons/yr. A table similar to Table 1 is Table 3. It is important to know the percent total solids (TS) as well as the percent volatile solid (VS) content of feedstock before anaerobic digestion as stated earlier. Table 3 is based on a constant minimum amount of feedstock of 30000 tons/yr and 5% contamination level. Total solids of eight feedstock with yearly methane yield had been presented graphically in Fig. 3(a) and (b) [3].

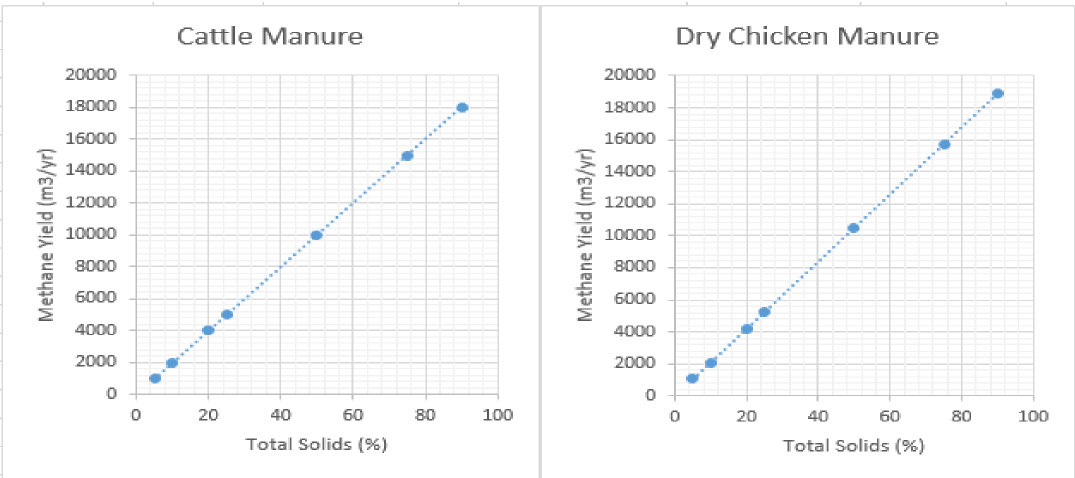


**Figure 3(a):** Cattle and Dry Chicken Manure Yield of Methane with Percent Total Solids

Fig. 3(a) and (b) can be used to estimate the biomethane yield of cattle manure, dry chicken manure, canola straw, barley straw, wheat straw, sewage sludge, sunflower straw and corn straw based on the percentage total solid present in them and compared with the empirical values obtained experimentally. The plots are based on 100 tons/yr of substrates following similar trend with Fig. 2 and Table 5.

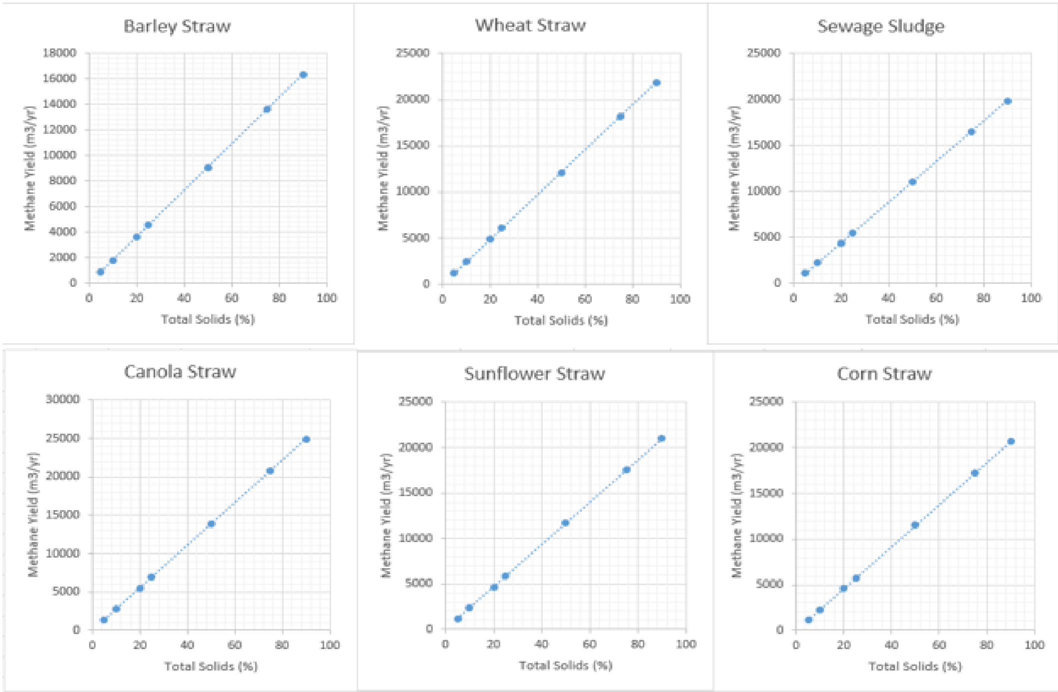


**Figure 3(b):** Methane Yield of Sewage Sludge and Crop Straws with Percentage Total Solids

Biogas yield are often presented in different units. The mathematical relationship (equation 2) [5] can interconvert the biogas yield in ($m^3$/kg total weight) to ($m^3$/kgVS) units:

$$Biogas\ yield\left(\frac{m^3}{kg\ of\ waste}\right) = Biogas\ yield\ \left(\frac{m^3}{kg\ of\ VS}\right).TS(\%).VS(\%) \quad (2)$$

**Table 3:** Biomethane Potential (BMP) of Various Feedstock [6]

| Feedstock | %TS | %VS | BMP | Biogas Production ($m^3$/yr) | Electricity Production (kWh) | Total Digestate (tons/yr) |
|---|---|---|---|---|---|---|
| *Chicken boiler* | 45 | 75 | 500 | 4809375 | 9476873 | 2268 |
| *Chicken layer* | 25 | 75 | 500 | 2671875 | 5264930 | 25267 |
| *Cow manure* | 25 | 80 | 450 | 2565000 | 5054333 | 25396 |
| *Fat, oils and grease (FOG)* | 36 | 84 | 1150 | 9911160 | 19529941 | 16507 |
| *Oat Hulls* | 90 | 87 | 242 | 5400351 | 10641392 | 21966 |
| *Pig manure* | 5 | 80 | 400 | 456000 | 898548 | 27948 |
| *Cheese whey* | 7 | 76 | 700 | 1061340 | 2091370 | 27216 |
| *WWTP sludge (5%TS)* | 5 | 80 | 350 | 399000 | 786230 | 28017 |
| *WWTP sludge (30%TS)* | 30 | 80 | 350 | 2394000 | 4717377 | 25603 |

Table 4 is the same as Table 3, only that it excludes the percent total solids and volatile solid there in the organic feedstock. More feedstock are reported compared to Table 3. Note that Table 4 is based on 100 tons/day of substrate.

**Table 4:** Heat, Electricity and Biogas Output of Different Substrate [7]

| **Type** | **Biogas Output ($m^3$)** | **Electricity Generated (kWt/h)** | **Heat Production (kWt/h)** |
|---|---|---|---|
| *Pig manure with litter* | 8390 | 1076 | 1113 |
| *Pig manure* | 7430 | 797 | 717 |
| *Sheep manure* | 10800 | 1064 | 1101 |
| *Cow manure* | 9000 | 806 | 834 |
| *Horse manure* | 6300 | 619 | 557 |
| *Hens manure* | 10000 | 1164 | 1205 |
| *Turkey dung* | 14030 | 1407 | 1456 |
| *Paunch manure* | 6050 | 595 | 535 |
| *Soy peeling waste* | 51670 | 4877 | 5046 |
| *Oat-flakes* | 61970 | 5938 | 6144 |
| *Oat* | 50110 | 4855 | 5024 |
| *Bran particles* | 26240 | 2383 | 2466 |
| *Dry bread* | 48200 | 4558 | 4716 |
| *Dairy wastes* | 67380 | 8145 | 8429 |
| *Casein* | 56740 | 7022 | 7266 |
| *Rape meal* | 49610 | 5313 | 5498 |
| *Sunflower meal* | 48820 | 5360 | 5546 |
| *Sunflower* | 59450 | 6761 | 6996 |
| *Sunflower oil* | 122260 | 14889 | 15407 |
| *Sugarbeet leaves ensilage* | 8820 | 859 | 889 |
| *Sugarbeet* | 14710 | 1338 | 1385 |
| *Haylage* | 20830 | 2018 | 2088 |
| *Lucerne* | 14100 | 1384 | 1432 |
| *Sudan grass ensilage* | 9800 | 923 | 955 |
| *Wheat* | 59820 | 5657 | 5854 |
| *Oil seed rape* | 64450 | 7583 | 7847 |
| *Potato* | 17710 | 1618 | 1674 |
| *Peas* | 58140 | 5727 | 5926 |
| *Onion peel* | 26780 | 3117 | 3226 |
| *Carrot* | 7330 | 681 | 613 |
| *Cauliflower* | 5920 | 592 | 533 |
| *Pumpkin* | 5090 | 487 | 576 |
| *Glycerine* | 84570 | 7573 | 7837 |
| *Linseed oil* | 122260 | 14889 | 15407 |
| *Rape-seed oil* | 119760 | 14585 | 15092 |

Also be reminded that, based on Biteco (2019) and Table 4, 1 ton/day of hens' manure = 100 $m^3$ of biogas = 10 kWt/h of electricity generated and 13 kWt/h of thermal energy production. For cow manure, 1 ton/day is equivalent to 90 $m^3$ of biogas which is equal to 7 kWt/h of electricity output and 9 kWt/h of thermal energy production. More so, 1 ton/day of sheep manure will give 108 $m^3$ of biogas, 9 kWt/h of electricity and 12 kWt/h of heat. A fifth table (Table 5) gives heat, methane yield and electricity data based on McCabe (2017) for a constant % total solid of 25% and constant flowrate of feedstock of 100 tons/yr:

**Table 5:** Data Based on 100 tons/yr of Feedstock and 25% TS

| **Type** | **Methane ($m^3$/yr)** | **Electricity generation (kWh/yr)** | **Heat generation (kWh/yr)** |
|---|---|---|---|
| *Cattle manure* | 5000 | 14555 | 21535 |
| *Dry Chicken Manure* | 5244 | 15266 | 22586 |
| *Wheat straw* | 627816 | 2203559 | 2059569 |
| *Barley straw* | 470368 | 1698598 | 1519419 |
| *Canola straw* | 715963 | 2512942 | 2348736 |
| *Sunflower straw* | 603914 | 2180864 | 1950813 |
| *Corn straw* | 593828 | 2144441 | 1918232 |
| *Sugarcane bagasse* | 779379 | 2735525 | 2556774 |
| *Potato peels* | 789675 | 2771665 | 2590553 |
| *Whey* | 93254 | 271468 | 401647 |
| *Sewage sludge* | 5513 | 16047 | 23743 |
| *Glycerin* | 10519 | 30621 | 45305 |

Chicken manure had been distinctively taken from Table 2 for analysis with Polymath regression tool. Table 6 follows the same pattern, but here, amount of feedstock (AF), electricity generation (EG) and heat generation (HG) were taken as independent variable while methane yield (MY) is taken as the dependent variable for a constant total solid content of 60%.

**Table 6:** Chicken Manure Biogas Output Data for 60% TS [3]

| **Amount (tons/yr)** | **Methane ($m^3$/yr)** | **Electricity Generation (kWh/yr)** | **Heat Generation (kWh/yr)** |
|---|---|---|---|
| 5 | 629 | 1832 | 2710 |
| 10 | 1259 | 3664 | 5421 |
| 18 | 2265 | 6595 | 9757 |
| 35 | 4405 | 12823 | 18972 |
| 56 | 7048 | 20517 | 30356 |
| 70 | 8810 | 25646 | 37945 |
| 80 | 10068 | 29310 | 43365 |
| 100 | 12586 | 36638 | 54207 |

The multiple nonlinear equation gives equation (3);

$$MY = a_0 + a_1 AF + a_2 EG + a_3 HG \tag{3}$$

where, the dimensionless constants, $a_0 = 0.0099882$; $a_1 = -396.5288$; $a_2 = 0.1724653$ and; $a_3 = 0.847122$, for range of AF = $5 - 100$ tons/yr, EG = $1832 - 36638$ kWh/yr and HG = $2710 - 54207$ kWh/yr.

**Table 7:** Poultry Waste Biogas Output with %Dry Matter [8]

| | **Poultry droppings** | | **Poultry litter** | |
|---|---|---|---|---|
| Dry matter % | Biogas output ($Nm^3/kg$) | Biofertilizer (tons/yr) | Biogas output ($Nm^3/kg$) | Biofertilizer (tons/yr) |
| 5 | 0.02063 | 0.00005 | 0.01386 | 0.00005 |
| 10 | 0.04125 | 0.0001 | 0.02772 | 0.0001 |
| 20 | 0.0825 | 0.00018 | 0.05544 | 0.00019 |
| 25 | 0.10313 | 0.00022 | 0.0693 | 0.00023 |
| 30 | 0.12375 | 0.00026 | 0.08316 | 0.00027 |
| 50 | 0.20625 | 0.00038 | 0.1386 | 0.00042 |
| 80 | 0.33 | 0.00048 | 0.22176 | 0.00059 |

To convert 1 $Nm^3$ to $m^3$, multiply by $10^{-27}$. Table 7 and 8 are from the same source, both reporting waste substrate(s) output of biogas, biofertilizer and other energy data with percent dry matter (DM) for 1 kg of feedstock. Similar table is seen in Table 3 and 9 but with different unit of the biogas production rate. The biogas output of poultry waste in Table 7 is directly proportional to %DM in the feedstock. Dry matter (DM) reflects the residual substance after complete elimination (drying) of water [9]. Common types of drying equipment for DM determination are forced air oven, Koster Tester, microwave, vortex dryer, food dehydrator and Near-Infrared Reflectance Spectroscopy (NIRS). To calculate DM of a feed, (i) weigh and record an empty container chosen to hold the material, (ii) put the material on the container and weigh them, i.e. container + sample weight, (iii) calculate the weight of the sample by subtracting weight of the container in (i) from the total weight in (iii), then place in a dryer, (iv) immediately after drying, weigh and record new weight of the container and material, (v) subtract the weight of the container from the weight in (iv) to know the weight of the material after drying and, (vi) divide the mass of the dry feed in (iv) by the mass of the wet material in (iii) and multiply by 100 [10]. These steps are further illustrated using Fig. 4. Mathematically,

$$\%DM = \frac{DW}{WW} \times 100 \tag{4}$$

where, DW = dry weight of sample and; WW = wet weight of original sample.

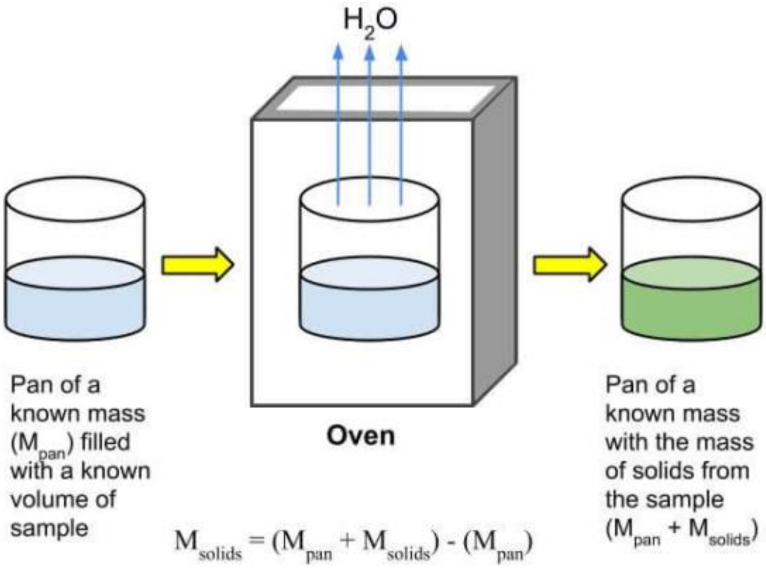


**Figure 4:** Procedure of Finding Total Solids Content in Water [11]

Dry matter content is simply referred to as total solids (TS) content. It is a term used for material left in a container after evaporation and drying of a sample at 103-105℃ [12]. Moisture content is the amount of water present in the feedstock. The difference in the initial weight (WW) and final weight (DW) of the sample represents the amount of water in the sample [13]. %TS or %DM and % moisture are related using equation 5 and 6:

$$\%DM = 100 - \%Moisture \tag{5}$$

$$\%Moisture = 100 - \%DM \tag{6}$$

**Table 8:** Important Biogas Data Based on 1 kg of Feedstock [8]

| Feedstock | Dry matter (%) | Biogas output ($Nm^3$/kg) | Electricity output (kWh) | LPG Equivalent (kg) | Biofertilizer (tons/yr) | $CO_2$ reduction (kg) | Slurry output (kg) | $CH_4$ Content (%) |
|---|---|---|---|---|---|---|---|---|
| Cattle dung | 18 | 0.05109 | 0.10787 | 0.02044 | 0.00017 | 39.53971 | 0.93869 | 55 |
| Cattle manure | 25 | 0.09 | 0.19 | 0.036 | 0.00022 | 69.6465 | 0.892 | 55 |
| Poultry litter | 38 | 0.10534 | 0.22238 | 0.04213 | 0.0003 | 88.92465 | 0.8736 | 60 |
| Poultry droppings | 28 | 0.1155 | 0.24383 | 0.0462 | 0.00024 | 97.5051 | 0.8614 | 60 |
| Spent grains | 26 | 0.13634 | 0.28784 | 0.05454 | 0.00022 | 113.18324 | 0.83639 | 59 |
| Barley straw | 86 | 0.31285 | 0.66046 | 0.12514 | 0.00054 | 220.09054 | 0.62458 | 50 |
| Glycerin | 98 | 0.686 | 1.44822 | 0.2744 | 0.00017 | 482.601 | 0.1768 | 50 |
| Potato (whole) | 22 | 0.099 | 0.209 | 0.0396 | 0.00019 | 73.82529 | 0.8812 | 53 |
| Potato peelings | 11 | 0.06783 | 0.1432 | 0.02713 | 0.0001 | 48.67306 | 0.9186 | 51 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Skimmed milk | 9 | 0.0626 | 0.13215 | 0.02504 | 0.00008 | 51.08274 | 0.92488 | 58 |
| Grain maize | 85 | 0.5814 | 1.2274 | 0.23256 | 0.00026 | 441.73609 | 0.30232 | 54 |
| Maize silage | 32 | 0.19853 | 0.41911 | 0.07941 | 0.00024 | 148.04431 | 0.76177 | 53 |
| Horse manure | 28 | 0.1176 | 0.24827 | 0.04704 | 0.00024 | 99.27792 | 0.85888 | 60 |
| Turkey manure + straw | 55 | 0.21038 | 0.44413 | 0.08415 | 0.00041 | 177.59858 | 0.74755 | 60 |
| Rapeseed oil | 99 | 1.19461 | 2.52195 | 0.47784 | -0.00043 | 1142.95238 | -0.43353 | 68 |
| Rapeseed straw | 80 | 0.18725 | 0.3953 | 0.0749 | 0.00062 | 136.99813 | 0.7753 | 52 |
| Rye meal | 86 | 0.57792 | 1.22005 | 0.23117 | 0.00026 | 455.35473 | 0.3065 | 56 |
| Sheep manure | 30 | 0.02592 | 0.05472 | 0.01037 | 0.00029 | 20.05819 | 0.9689 | 55 |
| Pig manure | 23 | 0.09315 | 0.19665 | 0.03726 | 0.0002 | 78.63723 | 0.88822 | 60 |
| Wheat | 86 | 0.5719 | 1.20734 | 0.22876 | 0.00027 | 450.61145 | 0.31372 | 56 |
| Wheat straw | 86 | 0.29195 | 0.61634 | 0.11678 | 0.00056 | 209.49657 | 0.64966 | 51 |
| Millet | 31 | 0.15861 | 0.33484 | 0.06344 | 0.00026 | 104.21666 | 0.80967 | 46.7 |
| Sugarbeet | 19 | 0.14508 | 0.30628 | 0.05803 | 0.00016 | 101.4514 | 0.8259 | 49.7 |
| Grape pomace | 28 | 0.0603 | 0.12729 | 0.02412 | 0.00026 | 47.33862 | 0.92765 | 55.8 |
| Cabbage leaves | 13 | 0.06503 | 0.13728 | 0.02601 | 0.00012 | 50.32037 | 0.92197 | 55 |
| Peanut bran | 93 | 0.43524 | 0.91884 | 0.1741 | 0.00044 | 379.67726 | 0.47771 | 62 |
| Glycerin | 10 | 0.8415 | 1.7765 | 0.3366 | -0.00001 | 591.99525 | -0.0098 | 50 |
| Whey | 5 | 0.0345 | 0.07283 | 0.0138 | 0.00005 | 25.727 | 0.9586 | 53 |
| Rumen content | 15 | 0.06048 | 0.12768 | 0.02419 | 0.00014 | 46.80245 | 0.92742 | 55 |
| Maize stalk | 50 | 0.1275 | 0.26917 | 0.051 | 0.00042 | 93.2841 | 0.847 | 52 |

Percent DM or TS is not constant for a particular feedstock. Though there are standards in the literature for comparison of experimental results. For instance, Chastain and his colleagues (2001) compared the TS content of chicken manure with turkey manure where they found that %TS in broiler litter, roaster litter and breeder litter are 78.5, 77.5 and 66.5 respectively; a value approximately closer to turkey manure feedstock. A high total solids level indicates a high level of solid material in the liquid sample [11]. It has been demonstrated in Fig. 3 as well as Table 7, that as the %DM of a specific substrate increases, the biogas or methane output also increase. The amount of material capable of being digested depends on two variables: the TS content and the volatile solids (VS) content of the material added to the bioreactor. Although, %VS content of feedstock are often extracted from the literature by researchers, there exist a formulae for its computation. This is shown in equations (7) and (8):

$$\%VS\ (mg/L) = \frac{weight\ of\ volatile\ solids}{weight\ of\ dry\ solids} \times 100 \qquad (7)$$

$$\%VS\ (mg/L) = \frac{weight\ of\ dry - weight\ of\ ash}{weight\ of\ dry\ solids} \times 100 \qquad (8)$$

**Table 9:** Dry Matter Percent of Various Feedstock with Biogas Yield [14]

| **Feedstock** | **Dry matter percent** | **Biogas Yield ($m^3$/ton)** |
|---|---|---|
| Cattle muck | 10 | 36 |
| Cow milk | 13.5 | 115 |
| Horse excrement | 28 | 63 |
| Pig muck | 22.5 | 74.25 |
| Poultry excrement | 15 | 56.25 |
| Sheep muck | 30 | 108 |
| Maize silage | 33 | 205 |
| Maize grain | 87 | 590 |
| Barley straw | 86 | 312 |
| Barley grain | 87 | 579 |
| Clover hay | 86 | 419 |
| Meadow hay | 86 | 426 |
| Oat straw | 86 | 314 |
| Oat grain | 87 | 501 |
| Rye grain | 87 | 597 |
| Wheat straw | 86 | 292 |
| Wheat grain | 87 | 598 |
| Wheat chaff | 89 | 262 |
| Wheat bran | 88 | 437 |
| Cauliflower | 9.6 | 59 |
| Fodder beet | 96.5 | 715 |
| Fodder carrot | 14.6 | 90 |
| Potato peeling | 11 | 68 |
| Sugar beet | 23 | 147 |
| Sour whey | 5.6 | 37 |
| Glycerin | 100 | 846 |
| Linseed oil | 99.9 | 1223 |
| Rapeseed oil | 99.9 | 1198 |
| Soya oil | 99.9 | 1223 |
| Sunflower oil | 99.9 | 1223 |
| Cheese waste | 99.9 | 674 |
| Old bread | 65 | 482 |

Carbon-to-nitrogen (C/N) ratio is one of the most vital nutrients necessary for the decomposition of organic substrate to bio natural gas. Nitrogen content is measured using combustion method and Kjeldahl method (TKN). Opinion differs as to the best C:N ratio that is best for anaerobic degradation of waste organic substrate. Generally, a ratio from 25:1 to 30:1 is accepted as the best C/N ratio so far [15]. Table 10 presents 63 substrate materials with their C/N ratios:

**Table 10:** C/N Ratios of Different Feedstock [15]- [16]

| Feedstock | C/N ratio | Feedstock | C/N ratio |
|---|---|---|---|
| Blood meal | 43:13 | Soybean stalk | 33:1.3 |
| Cow manure | 12-25:0.6-1.7 | Peanut shoots | 20-31:0.6 |
| Cow dung | 16-25:1.8 | Peanut hulls | 31:1.7 |
| Chicken dung | 5-9.65:3.7-6.3 | Peanut shells | 35:1 |
| Chicken manure | 7-7.3:1-6.3 | Potato peels | 25:1.5 |
| Poultry bedding | 15:1 | Potatoes | 35-60:1 |
| Poultry manure | 5-15:1 | Coffee grounds | 14-25:1 |
| Pugo | 6.74:5 | Nut shells | 35:1 |
| Waterlily | 11.4:2.9 | Sugarcane bagasse | 140-150:0.3 |
| Horse manure | 20-50:1-2.3 | Sugarbeet | 35-40:1 |
| Rabbit manure | 17.9:1 | Saw dust | 200-600:0.1-1 |
| Deer manure | 25.72-30.06:1 | Wood chips | 25-50:0.1 |
| Goat manure | 10-20:1 | Newspaper | 50-200:1 |
| Pig manure | 6-12.5:1-3.8 | Tissue paper | 70:1 |
| Sheep manure | 13-33:1-3.8 | Paper | 170-173:1 |
| Sheep dung | 30-33:1 | Cardboard | 378:1 |
| Elephant dung | 43:1 | Rice straw | 51-67:0.6 |
| Human excreta | 8:1 | Corn straw | 50:0.8 |
| Legume Hay | 17-40:1-2.5 | Corn stalk | 56.6-75:1-1.2 |
| Hay | 12.5-25:1-4 | Corn cobs | 49.9-123:1 |
| Lucernes | 16.6:2.8 | Wheat straw | 50-150:0.5-1 |
| Algae | 75-100:1.9 | Oat straw | 48-70:0.5-1.1 |
| Cabbage | 12.5:3.6 | Rye straw | 82:1 |
| Tomatoes | 12.5:3.3 | Silkworm | 11.28:1 |
| Alfalfa | 12:1 | Humus | 10:1 |
| Clover | 23:1 | Sludge | 6:1 |
| Mushroom residue | 21.96-23.11:1 | Hog | 13.7:2.8 |
| Grass silage | 10-20:1 | Carabao | 23.1:1.6 |
| Mulberry leaves | 14.85:1 | Peat moss | 58-60:1 |
| Water hyacinth | 25:1 | Pine needles | 60-100:1 |
| Seaweed | 70-79:1-1.9 | Hairy vetch | 11:1 |
| Mustard (runch) | 25:1.5 | | |

## 3. Conclusion

This work did not report the amount of all nutrient content in feedstock for anaerobic digestion. Essential output data on codigestion of multiple feedstock were not presented too. Also, not all substrates for anaerobic production of biogas were captured. Again some of the data tables appears to be the same. Notwithstanding, this article hopes to provide some relevant data for researchers to compare their empirical biogas data for accuracy and analysis.

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