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POTENTIAL OF BIOGAS FROM ANIMAL WASTES OF TURKEY AND DETERMINATION OF SUITABLE REACTOR SIZE

SUMMARY

There is an intensive agricultural production performed in Turkey, where 62.3% of total agricultural holdings engage in both crop production and animal husbandry, while 5% of total holdings are engaged with only animal production. According to the statistics of cattle, sheep and poultry enterprises in Turkey, approximately 161 million tons of waste is obtained from these sectors. The animal wastes cause huge problems for enterprises and cannot be reutilized properly. Thus, producing biogas by using these wastes is the best method to reutilize them. According to the research conducted in this area, the amount of biogas supplied from animal wastes is 7.62 Gm^3/year and its energy equivalent value was calculated as 66.3 PJ.

In Turkey, 85% of animal wastes are obtained from cattle farming. Considering the size of the cattle enterprises in Turkey, 59.78% of the owners have 1-4 cattle, 21.3% of them have 5-9 cattle, 12.8% have from 10 to 19 cattle, 5.4% have about 20-49 cattle, 0.7% have about 50-149 cattle and 0.1% of farm owners have 149 or more cattle in their farms. In this study, sizes of eligible biogas units for enterprises were calculated as well. The size of the proposed biogas reactor is 7 m^3 for the farms based on their current waste potential for 10 cattle, 14 m^3 for 20 cattle, 36 m^3 for 50 cattle, 108 m^3 for 150 cattle and 215 m^3 for 300 cattle, respectively.

Keywords: Animal waste, biogas, biogas potential, size of biogas reactor.

INTRODUCTION

Turkish energy demand is rapidly increasing due to demographic and economic growth of the country (Yüksel et al., 2010; Demirbaş, 2001). Turkey is a dependent country in terms of energy due to the limited resources, which

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results in importing expensive energy sources in order to meet the energy demand of the country.

Therefore, many debates and discussion are going on regarding The Renewable Energy Sources (RES) to see whether the RES meet Turkey's energy needs economically and they can be a solution of environmental pollution problem (e.g. air pollution) caused by the use of fossil fuels. Referring to this debate, it can be clearly said that the RES applications are the most powerful key for efficient, clean and sustainable energy development of Turkey.

According to the data obtained from Ministry of Energy, Industry and Technology; Turkey consumes three times more energy than it can produce. Therefore, the ratio of imported energy requirement is over 70% (Azbar, 2011). The primary energy resources of Turkey consist of lignite, hydro and biomass energy. Electricity is produced by using mainly coal, lignite, natural gas or fuel oil in thermal power plants. Geothermal energy and hydroelectric power plants constitute the other major energy resources (Demirbaş, 2008). Evaluation of domestic energy resources will allow eliminating Turkish dependence on fossil energy sources and providing sustainable energy (Öztürk and Başçetinçelik, 2006).The policy studies related to renewable energy and use of technology in Turkey are conducted on the subject of basic research often comprise hydroelectric power and geothermal heat. In practice, there is no enough work showing contribution of using and application of biomass to energy production. Biomass energy potential of Turkey is quite high. Therefore, focusing on renewable energy resources is not sufficient in the long-term political strategy; instead, biomass (biogas, biodiesel, bioethanol) energy resources must be considered on a national scale to be developed.

Livestock sector in Turkey is composed of small-scale farms in general. Low productive native species are grazed mostly in meadows and pastures. Small livestock enterprises have higher production costs with lower yields. Interest in the livestock sector is quite high especially by foreign investors (Anonymous, 2006). The problems related to animal waste start with the process of collection. Especially in the eastern regions, long grazing periods makes it impossible to collect the animal waste, whereas collecting the animal manure is more efficient in western part of Turkey since the animals are reared in a modern barn without grazing. There are more larger-scale farms and enterprises in the Western part of Turkey compared to the Eastern side. Livestock is the most important livelihood resource in the eastern regions. The small size enterprises with few animals are commonly seen in the eastern region.

Animal waste collection is usually done in the pits found in the barn; this waste is collected in a trough with water from the farm and then discarded. These aqueous wastes require storing in temporary storages in the fields located outside of the barns. However, the temporary storage areas have no impermeability standards specified and this situation leads to contamination of groundwater resources, which is a major environmental problem. The most common method of disposal of animal wastes is to discharge them into the closest aquatic environment.

MATERIAL AND METHODS

In this study; the reactor size was calculated by considering the amount of waste based on the holding size of the farms (animal presence in farm). In determination of the reactor size; amount of raw material, the amount of water added and the hydraulic retention time were taken into consideration. It has been observed that the efficiency of the process increases due to rate of proliferation and fragmentation reactions more quickly with the increasing temperature in anaerobic processes (Öztürk and Başçetinçelik, 2006). As it is known, the production of biogas at 9-15 °C almost stops. The mesophilic temperatures (35-37 °C) in biogas systems are usually preferred during the production process (Ersayar, 2007).

The ambient temperature is directly related to the retention time of animal waste. Retention time decreases when the ambient temperature is increased. Higher temperatures cannot be applied in small villages; because a certain portion of the energy obtained is used for heating. The ambient temperature should be kept between 30-40°C by means of a good insulation and solar energy. In this case, the retention time is reduced to 20 days. The retention time and its relationship with temperature are given in Table 1. The capacity of the gas collecting chamber of the reactor must be at least as high as the daily gas production to store the daily gas product (Entürk, 2004).

Table 1. Relation of Temperature and Retention (HRT) Time (Eryaşar, 2007)

Heat (°C)	HRT (day)
10-20	100 and more
20-35	20
50-60	8

RESULTS AND DISCUSSION

Although Turkey's surface area is 814.578 km2, the total area of the farmlands including the fallowing lands is 238.106 km2, which is approximately 30% of total surface area. Turkey can be considered as a self-sufficient country with its great potential of crop and animal production. Crop production, cattle activities and small ruminants have important place in the economy of the country.

There is a total of 3.057.100 of animal holdings in Turkey. Considering the number of enterprises engaged in crop and animal production, the ratio of enterprises engaged only in crop production is 62.3%, while 37.2% of the enterprises engaged in crop and livestock production together and 0.5% of enterprises engaged livestock only. Turkey's total livestock figures are given in Table 2.

Considering the distribution of animals based on the regions of Turkey, the Eastern Anatolia has 19.68% of bovine and 26.05% small ruminants stock, whereas South Eastern Anatolia Region is the last region in terms of the number of cattle. Poultry existence of Turkey is in the Marmara and Aegean regions due

to the economy and trade policies. These two regions of Turkey provide 50% of poultry production. The number of animals and their distributions in Turkey are given in Table 3.

Table 2. Livestock Figures of Turkey (Anonymous, 2013)

Species	**Mature**	**Young**	**Total**
Buffalo	93711	23880	117591
Cattle(Pure bred)	4386066	1568267	5954333
Cattle (Cross-breed)	4654974	1457463	6112437
Cattle (Local)	1806717	541770	2348487
Sheep (Local)	21166970	6318196	27485166
Sheep (Merino)	1354407	444674	1799081
Goat (Hair)	6748815	2310444	9059259
Goat (Mohair)	126844	39445	166289
Broiler			177432745
Layer			88720709
Turkey			2925473
Goose			755286
Duck			367821

Table 3. Regional Livestock Numbers and Their Distribution in Turkey

Region of Turkey	Cattle	(%)	Small Ruminant	(%)	Poultry	(%)
Eastern Anatolia	3141162	19.68	10055247	26.05	9311632	2.75
Southeastern Anatolia	974670	6.50	6911054	17.87	4582798	1.86
Reg. of Marmara	2229166	16.34	4153050	10.85	115977406	41.68
Reg. of Aegean	2087819	15.39	4681456	11.92	77834229	29.30
Reg. of Cent. Anatolia	2595138	18.44	6526324	17.48	30508716	12.35
Reg. of Mediterranean	1236382	8.77	4477002	11.47	14911115	5.53
Reg. of Black Sea	2264282	14.87	1705662	4.36	17076138	6.54

There are many factors that influence the amount of waste emerged and the amount of biogas that can be derived from livestock holding as follows; the breeding characteristics of animal species, feeding type, body weight, total solids quantity, volatile solids content and availability of waste and biogas efficiency. The average values of these factors were given in Table 4.

Compound feed having 8-13% of the total dry matter (TDM) is suitable for the production of biogas. Solids in the material are precipitated in the event of very low solids content (Al-Azzam, 2003). Solid matter contents are; 5-25% of cattle manure, 10-90% of poultry manure, and about 30% of sheep manure respectively. The use of extra water during the collection of animal waste reduces

the total solid range to 2-5%. It can also reduce the system efficiency by spending a lot of energy to heat the water.

Table 4. Waste Features in Terms of Livestock

Livestock	Average Live weight (kg)	Amount of Wet Waste		Total Solid (%)	Volatile Solid (kg)	Usability Length of Stay (%)	Biogas Efficiency (l/kgUK)
		% of weight	kg/day				
Cattle	150 - 800	6 - 8	10 - 50	5 - 25	75 - 85	Beef 65 Dairy 25	200- 350
Small Ruminant	30-75	3 - 4	1- 3	20 - 22	20 - 22	13	100-310
Poultry Broiler Layer	1.5 - 2.0	3 -4	0.08-0.10	10 - 35 50 - 90	70 - 75 60 -80	99	310-620 550-650

The quantities of animal waste vary according to the diet of animals, size, climate conditions and raising methods. If the animals are being kept only at nights, the waste to be emerged should be calculated as 50% of the total waste. When the animals are kept in a land pens, it is difficult to collect waste and it cannot be possible to prevent the entry of unsuitable materials such as sand and stones into the reactor. In addition, urine is completely lost. Straw should be no more than 2-3 cm in length if used and non-fermented wood flour should not be used (Eryaşar, 2007). When the animals graze in pasture, collected waste and therefore the biogas production is greatly reduced during the summer months. Keeping length of livestock in the barn are; 65% for dairy cattle, 25% for beef cattle, 99% for poultry and 13% for small ruminants, respectively (Acaroğlu, 2007; Başçetinçelik et al, 2007).

It is an essential to have continues energy for enterprises in order to run their production processes and operations, and the gas must be constant from the biogas plant if energy demand of the company is supplied from biogas production. Otherwise, enterprises cannot continue their daily activities. Therefore, biogas production from animal and vegetable waste reactors will be designed for the realization of "continuous fermentation" process, which is required for manufacturing.

In the calculation of amount of the wet waste; the average live weights taken into consideration are as follows; pure breeds 450 kg, cross-breeds 400 kg and local breeds 350 kg, respectively. The wet waste ratio was taken as 8%, 7% and 6%, respectively. Additionally, the average live weight of the buffalos is 450 kg and 7% value was determined for the amount of waste. Live weight values of the small ruminants such as native sheep, merino sheep, goat and Angora are as follows: 40 kg, 45 kg 35 kg and 40 kg, respectively. Considering the amount of waste for all small ruminants, the ratio was calculated as 3% of live weight of the

animals. The average live weight was 1.5 kg and 80-100 g/day wet waste was obtained from poultry. The availability of waste was 50% for cattle, 13% for small ruminants and 99% for poultry in terms of the standing time in Barn of Livestock, respectively. The amount of waste that can be obtained from livestock is presented in Table 5.

Table 5. Waste Amount in Terms of Livestock

Livestock	Wet Manure (ton/year)	Dry Matter rate (%)	Dry Matter Amount (Year)	The Waste Usability (%)	Total Dry Matter Amount (ton/year)
Cattle	135 625 653.837	15	20 343 848.075	50	10 171 914.037
Small Ruminant	14 963 150.965	30	4 488 945.289	13	583 562.887
Poultry	10 587 815.509	35	3 705 735.428	99	3 668 678.073
Total	161 176 620.311		28 538 528.792		**14 424 154.997**

The total amount of waste that can be achieved is determined as 14424154.997 tons/year related to dry matter rate. In calculation, the amount of biogas that can be obtained from 1 tons of solid animal waste is approximately 200 m^3 and the calorific value of biogas has been accepted as 22.7 MJ. Obtainable biogas potential of animal waste is shown in Table 6.

Table 6. The Amount of Biogas That Can be obtained from Animal Waste

Livestock	Total obtainable Solid Waste Amount (ton/year)	Obtainable Biogas (m^3/year)	Calorific Value (GJ/year)
Cattle	10 171 914.037	2 034 382 807.400	46 180 489.727
Small Ruminant	583 562.887	116 712 577.400	2 649 375.507
Poultry	3 668 678.073	773 735 614.600	17 563 798.451
Total	14 424 154.997	2 924 830 999.400	**66 393 663.685**

As it is seen in Table 6, the annual amount of biogas that can be obtained from animal wastes is 2 924 830 999.4 m^3 in Turkey, which is equal to 66 393 663.685 GJ of energy. The largest share belongs to the waste of cattle in terms of amount of the production. The rate of bovine in the total amount of wet waste is 84%, whereas small ruminants 9% and poultry7%, respectively. The rates of these animals in total solids are found as 70%, 4% and 26%, respectively. The size of cattle and sheep enterprises engaged in the production and distribution of animal species were given in Table 7.

The amount of obtainable wet waste was determined by multiplying the amount of waste with daily fresh length of stay in the barn. The volumetric specific gravity of the waste was found as 975 kg/m^3 (Ak, 2008). The rate of amount of water required for conversion of the solid matter was calculated as 15% down to 9%.

Table 7. The Size of Cattle and Sheep Enterprises Engaged in the Production and Distribution of Animal Species in 2013

Holding size according to number of bovine animals (head)	Holdings having bovine animals (%)*	Bovine animals (%)*	Holding size according to number of sheep and goats (head)	Holdings having sheep and goats*	Sheep and goats*
1 – 4	59.7	21.6	1 – 4	18.6	1.0
5 – 9	21.3	21.3	5 – 9	10.8	1.6
10 – 19	12.8	25.4	10 – 19	17.2	4.9
20 – 49	5.4	22.9	20 – 49	25.3	16.8
50 – 149	0.7	7.0	50 – 149	21.1	36.1
150 – 299	0.0	1.2	150 – 299	5.6	24.1
300 +	0.0	0.6	300 +	1.5	15.6

**Since expansion coefficient of this sampling survey was used with decimals, the total numbers may not be exact due to the rounding of the numbers*

Amount of the material required to be operating the biogas plant was determined by addition of daily wet waste and water added. The volume of the reactor was determined by multiplying the amount of material with hydraulic retention time. Capacities of biogas plants and biogas production quantities for Turkey's bovine holdings depending on animal capacity are presented in Table 8.

Table 8. The Capacity of Biogas Plants and Biogas Production Quantities for Turkish Bovine Holdings Depending on Their Animal Capacity

Bovine Numbers	The average amount of estimated available wet waste		Amount of water added %9 (m^3)	Hydraulic retention time	Reactor volume (m^3)	The amount of biogas production (m^3/day)
	(kg/day)	(m^3/day)				
10	140	0.143	0.095	30	7	4.05
20	280	0.287	0.191	30	14	8.10
50	700	0.718	0.479	30	36	20.83
150	2100	2.154	1.438	30	108	186.65
300	8400	4.307	2.877	30	215	371.58

The volume of biogas reactor in terms of 30-day holding time ratio and 9% of solid ratio for production of biogas from livestock are calculated as 7 m^3 for holdings with 10 animals, 14 m^3 with 20 animals, 36 m3 with 50 animals, 108 m^3 with 150 animals, 215 m^3 with 300 animals, respectively

CONCLUSIONS

Turkey has 66.4 million PJ of energy potential and 7.62 billion m^3 of biogas that can be produced from 161 million tons of wet waste annually. In Turkey, cattle are raised widely. The cattle waste has a share of 84% in total animal waste. The average cattle holdings have 10-50 head of cattle. According

to the existing waste, the potential of the proposed biogas plant reactor size; is 7 m^3 for holdings with 10 cattle, 14 $m^3$with 20 cattle, 36 m^3 for 50 cattle, 108 m^3 for 150 cattle and 215 m3 for 300 cattle, respectively. The estimated daily amounts of biogas to be obtained from these holdings are 4.05 m^3, 8.10 m^3, 20.83 m^3, 186.65 m^3 and 371.58 m^3, respectively. Biogas obtained from these facilities can be used for the production of electricity production, for cooking and heating purposes such as heating the water or houses. The main output of the biogas production is a fertilizer containing organic matter. This fermented fertilizer was purified from pathogens and can be used in crop production as an organic material.

Processing of the animal wastes by the way of anaerobic fermentation, obtaining fermented manures and the use of renewable energy will result in reduction of environmentally harmful waste and waste management costs. Economically, the initial investment costs are as high as biogas systems, which indicate that it is an expensive alternative energy resource. The small-scale biogas plants are expected to be able to amortize themselves in about 8-10 months if they run in full capacity (Ertürk, 2004). However, for the establishment of the biogas plants, there is a need of financing at the preliminary stage. This funding can be provided by government-backed foreign loans or private loans. In many countries, the programs that have environmental and health benefits by using biogas technologies have been initiated by the governments. The incentives and loans must be widely used to reduce the burden of the costs that people have to face during the establishment of the biogas systems.

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