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Araştırma Makalesi – Research Article

Livestock Waste-Based Biogas Energy Potential of Tokat Province and Possible Implementations*

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Abstract

Tokat Province has intensive livestock facilities. The present study was conducted to determine biogas production potential from livestock wastes and to assess energy production opportunities and possible resultant contributions to be made to country economy. The target is to create high-yield, easily constructed and feasible biogas facilities with low investment, operation and maintenance costs. Initially the number of livestock facilities and their waste potentials were determined and energy production potential from these wastes was assessed. Current calculations and assessments revealed that Tokat Province has biogas production potential of 301 434 m^3/day with an electrical energy equivalent of 502 390 kWh/day. Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock wastes among the animal wastes were taken into consideration and pilot central biogas facilities were designed for 250 animal capacities. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning, energy analyses and costing were performed for those facilities. ArcMAP software was used in analyses to determine the locations, numbers and capacities of biogas facilities based on animal intensities and distances between rural settlements.

Keywords: Biogas, livestock waste, energy, Tokat

Tokat İlinin Hayvansal Atık Kaynaklı Biyogaz Enerjisi Potansiyeli ve Uygulanabilirliği

Özet

Hayvansal üretimin yoğun olarak yapıldığı Tokat ilinin hayvansal atıklarından elde edilen biyogaz potansiyelinin belirlenmesi, enerji üretiminde değerlendirilme olanakları ve ekonomiye katkısının belirlenmesi amacıyla yapılan bu çalışmada; Tokat ilinin kırsal kesimine yönelik yüksek verimli, yatırım, işletim ve bakım maliyetleri uygun, kolay kurulum ve kullanım özelliklerine sahip, biyogaz sistemlerinin oluşturulması hedeflenmiştir. Bu bağlamda Tokat ilindeki yetiştiriciliğinin yoğun olarak yapıldığı güncel büyükbaş hayvan işletme sayıları belirlenmiş enerji üretim potansiyeli araştırılmıştır. Elde edilen sonuçlardan Tokat ilinin biyogaz üretim potansiyelinin 301 434 m^3/gün ve elektrik enerjisi üretim miktarının 502 390 kWh/gün olduğu belirlenmiştir. Yöredeki büyükbaş hayvan varlığının fazla olması ve büyükbaş hayvan atıklarının daha kolay sağlanabilmesi nedeniyle 250 büyükbaş hayvandan elde edilebilecek atıkların değerlendirileceği örnek merkezi biyogaz tesislerin planlanması yapılmış, AutoCAD programıyla taban planları, kesit ve cephe görünüşleri çizilmiş, tesislerin boyutlandırılması ve enerji analizleri hesapları yapılmıştır.

Anahtar Kelimeler: Biogaz, hayvansal atık, enerji, Tokat

* This study presents partial results of a Graduate Thesis

Introduction

Ever increasing energy demands have brought about the needs to find new energy sources. With currently available potential, socioeconomic benefits and differences from the other energy sources, biogas may be considered as an alternative energy source. Biogas technology allows to make organic wastes creating various problems on environment and human health harmless and to use such wastes in energy production. It is also a significant factor with regard to renewable energy production.

Energy is an indispensable part of human life and is a significant indicator of economic and social development. It is highly effective in improvement of life standards and plays a vital role in technological production and development. Fossil fuels have commonly been used to meet world energy demands for ages. But is evident that such resources will not be able to meet the demands of mankind in near future and consequently an energy bottleneck is envisaged for the upcoming years.

So, renewable energy sources should be investigated and put into practice to overcome this prospective bottleneck in energy supply.

Agricultural, livestock and domestic wastes are considered as an alternative source of energy in Turkey as it was in various other parts of the world to meet a portion of energy demand and to overcome the problems related to energy resources. Therefore, there is a need for research to assess the energy production potential of such wastes, about the anaerobic digestion conditions and proper digesters. The studies on biogas production technologies should be supported and anaerobic treatment technologies should be developed.

There are 36 biogas facilities actively operating in Turkey and 34 of them are operating as the facilities of municipalities or industries (waste gas or wastewater treatment facility). These facilities are commonly located in western regions of the country. The number of facilities using livestock waste or additives is 18. Together with the facilities under construction, the number will reach to 85 (Turkmenler et al., 2014; Anonymous, 2014).

Despite the available organic waste potential (38 million tons), these wastes are not properly valued in Turkey. A significant economic input can be supplied by using these wastes (Turkmenler et al., 2014). About 85% of total biogas potential comes from waste gas and the rest comes from solid waste repository gas. Of waste gas potential, 50% comes from ovine, 43% comes from bovine and 7% comes from poultry (Topal et al. 2008). Considering the animal waste theoretical biogas potential, the annual potential was estimated to be 2 608,3 million m^3, 401,5 million m^3 of which coming from poultry, 852,6 million m^3 from ovine and 1 354,2 million m^3 from bovine. Therefore, biogas potential of Turkey is estimated to be 1 400-2 000 Btep/year. Biogas sector of Turkey is composed of waste gas production facilities of some municipalities, waste water treatment facilities of municipalities, and industries, gasification demonstration facilities of the Ministry of Forest and Water Works and specialized biogas facilities of private sector. Biogas production is also performed from livestock wastes with investments made in this area (Anonympus, 2012).

For proper implementation of biogas technologies in Turkey, regional or local potentials should initially be determined. Tokat Province of Turkey has significant potential with regard to agricultural and livestock activities. Total livestock inventory of the province is 384 795 bovines, 258 944 ovine (sheep and goats) and 248 156 poultry (Anonymous, 2014). The province has also significant infrastructure and land resources for

energy forestry and biofuels. However, biomass energy production from plant materials, livestock and forest wastes, grass lands, domestic and industrial wastes is not still at desired levels (Karaman and Ozguven, 2012). Livestock wastes are piled up over the fields and burnt as cowpat and such uses result in various environmental problems (Karaman, 2005). Despite the rapid growth of livestock industry of the province, possible use of livestock wastes and their conversion into energy sources are not assessed sufficiently. Thus, researches are needed to assess biogas production potential of these livestock wastes of the province.

The present study was conducted to determine the biogas production potential of livestock wastes of Tokat Province with intensive livestock facilities, to identify possible use of these wastes in energy production and to determine the contributions provided to economy. Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock wastes among the animal wastes were taken into consideration and pilot central biogas facilities were designed for 250, 500 and 1 000 animal capacities. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning, energy analyses and costing were performed for those facilities.

Material and Method

Material

The present study was conducted to determine livestock inventory of Tokat Province and to assess biogas production potential from livestock wastes. Therefore, initially, characteristics of current livestock facilities, their livestock inventories, distribution throughout the province, land resources and distribution, population distribution and geographical characteristics were investigated. Relevant data was gathered from Tokat Provincial Directorate of Food Agriculture and Livestock, TUIK (Turkish Institute of Statistics), DMI (State Meteorological Works).

Method

The equations provided in Ergunes and Tarhan, (2009) were used to calculate daily manure production, daily slurry amount, amount of water to be added to manure, daily total slurry volume, reactor (digester) volume (RH), total specific gas production, daily gas production, volume of gas tank.

In calculation made to determine biogas potential, optimum biogas conditions were assumed and the recommendations provided in Ergunes and Tarhan, (2009) were considered to calculate daily manure production of an animal, biogas reactor volumes for different size facilities and hydraulic retention times.

Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock wastes among the animal wastes were taken into consideration and pilot central biogas facilities were designed for 250, 500 and 1 000 animal capacities. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning was performed for those facilities.

The principles provided in Kaya and Ozturk (2012) were taken into consideration while calculating daily organic matter to be fermented or loaded into reactor (reactor loading) and reactor height. Reactor loading was taken as 5 kg/m^3/day as recommended and 33 m^3/day gas production was assumed per ton of manure (Kaya and Ozturk, 2012).

Reactor sizing was performed by considering the recommendation provided in Kaya and Ozturk (2012) for vertical cylindrical floating balloon type biogas facilities. Reactor

diameters were taken as equal to reactor heights and the ratio of RH/GD=3/1was taken while calculating gas tank volumes (Kaya and Ozturk, 2012). While calculating livestock waste-based biogas production potential of the province, 30% of gas was assumed to be electricity, 60% heat and 10% loss through cogeneration method of the gas and thermic equivalent of biogas was taken as 20 MJ/m^3 (Kaya and Ozturk, 2012; Gulen and Arslan, 2005).

Results and Discussion

Biogass Potential of Tokat Province and Enerji Equavelents

There are 384 795 bovines, 258 944 ovine and 248 156 poultry of which 239 805 are hens and 8 351 are the other poultry (Table 1). Of this livestock inventory, 55% are local races, 35% are hybrid and 10% are culture races. The ratio of culture races was significantly at low levels. Of total ovine inventory, 84% are sheep and 16% are goats. Of total poultry inventory, 91% are hens, 3% are goose, 2% are turkey and 2% are duck. Of livestock facilities, 63% have an animal inventory of 1-10, 2% have 11-20, % have 21-30, 3% have 31-40, 1.5% have 41-50, 1.4% have 51-100 and only 0.2% have an animal inventory of over 101. Of this bovine inventory, 70.5% are dairy cows and 29.5% are beef cattle (Anonymous, 2014).

Table 1. Animal inventory of towns of Tokat Province (Anonymous, 2014)

Towns	Bovine	Ovine	Hen	Other Poultry
ALMUS	20 702	18 687	10 355	852
ARTOVA	17 510	6 759	6 430	376
BAŞÇİFTLİK	5 434	3 581	2 890	395
ERBAA	32 112	54 492	48 797	1 363
MERKEZ	76 090	51 523	48 321	1 564
NİKSAR	52 455	30 811	28 328	679
PAZAR	12 646	5 531	5 865	118
REŞADİYE	23 322	23 040	20 743	467
SULUSARAY	14 189	4 072	3 567	301
TURHAL	58 539	33 941	31 021	985
YEŞİLYURT	14 945	6 002	5 032	234
ZİLE	56 851	20 505	28 456	1 017
TOPLAM	384 795	258 944	239 805	8 351

The amount of waste to be obtained from bovine (7 696 ton/day) was higher than the waste to be obtained from ovine and poultry. Thus, central biogas facilities using livestock (ovine) manure was decided to be designed since livestock facilities are common in the region and it is easy to collect livestock waste. Since 85% of livestock facilities have less than 20 animals, central facilities serving more than one facility were found to be proper. Large portion of livestock facilities (83%) also deal with plant production activities, these facilities can be organized as biogas cooperatives and use both livestock and plant production wastes together in biogas production.

Livestock-based biogas potential of Tokat Province and energy equivalents are provided in Table 2.

Table 2. Total biogas potential of Tokat Province and energy equivalents

TOWNS	DMP (ton/day)	Reactor volume (m^3)	DGP (m^3/day)	Total energy equivalent (kWh/day)	Cogenerated energy equivalents (kWh/day)		
					Electricity	Heat	Loss
ALMUS	453	29 452	16 895	93 861	28 158	56 317	9 386
ARTOVA	364	22 673	12 942	71 900	21 570	43 140	7 190
BAŞÇİFTLİK	117	7 401	4 244	23 578	7 073	14 147	2 358
ERBAA	755	51 964	30 227	167 928	50 378	100 757	16 793
MERKEZ	1 629	104 000	59 660	331 444	99 433	198 867	33 144
NİKSAR	1 113	70 545	40 392	224 400	67 320	134 640	22 440
PAZAR	264	16 538	9 451	52 506	15 752	31 503	5 251
REŞADİYE	514	33 665	19 399	107 772	32 332	64 663	10 777
SULUSARAY	292	18 030	10 267	57 039	17 112	34 223	5 704
TURHAL	1 241	78 609	45 009	250 050	75 015	150 030	25 005
YEŞİLYURT	311	19 411	11 075	61 528	18 458	36 917	6 153
ZİLE	1 180	73 275	41 873	232 628	69 788	139 577	23 263
TOTAL	8 234	525 563	301 434	1 674 633	502 390	1 004 780	167 463

DMP: Daily Manure Production, DGP: Daily Gas Production

Design of Central Biogas Facilities for Tokat Province

Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock manure among the animal wastes were taken into consideration for biogas production. Since biogas facilities have high initial investment costs and return on investment takes longer, livestock manure is not well utilized in the region and excessive manure haphazardly piled up over the fields and result in various environmental problems, pilot biogas facilities were designed for 250, 500 and 1 000 bovine manure capacities. Collection and storage of manures of rural settlements at a certain place will reduce the facility cost, time and labor losses. Environmental problems will also be eliminated through the use of such wastes in biogas production.

Besides livestock wastes, other agricultural wastes, food and fishery industry wastes, organic domestic wastes and sewage wastes can used in central waste collection systems and biogas facilities and all these works can be carried out by a cooperative established by the farmers.

In several parts of the world with intensive livestock facilities, livestock wastes are transported to central biogas facilities with transportation vehicles. Biogas is produced from these wastes and converted into energy for heat and power generation. The fermented manure is then transported to storage tanks close to facilities to use in agricultural lands (Yokus, 2011). In central biogas facilities, livestock and other wastes are sent from pre-storage tanks or canals and special storage trucks to reactors. In-place storage, transfer and transport of resultant fertilizer are all the responsibility of farmers in thse facilities. Manure storage sites can be used more than one farmer. Based on mesophilic and thermophilic processes, hydraulic retention time in these facilities is between 12-25 days and biomass mixture is taken inside with pumps. Pumps are also used to take out from the reactor at equal amounts (Gul, 2006).

Gas productions and energy equivalents of recommended biogas facilities are provided in Table 3.

Table 3. Gas productions and energy equivalents

Number of livestock	Reactor load (kg/m^3/day)	DMP (ton/day)	DGP (m^3/day)	Total energy equivalents (kWh/day)	Cogenerated energy equivalents (kWh/day)		
					Electricity	Heat	Loss
250	1.66	5	170	944	283	567	94
500	1.66	10	340	1 889	567	1 133	189
1 000	1.66	20	679	3 772	1 132	2 263	377

DGP: Daily Gas Production, DGP: Daily Gas Production

Reactor and gas tank dimensions for recommended facilities are provided in Table 4.

Table 4. Reactor and gas tank dimensions

Number of livestock	Reactor			Gas tank		
	Volume (m^3)	Height (m)	Diameter (m)	Volume (m^3)	Height (m)	Diameter (m)
250	300	7.25	7.25	100	3.63	7.25
500	600	9.15	9.15	200	4.58	9.15
1 000	1 200	11.50	11.50	400	5.75	11.50

Volume of pretreatment tank was calculated based on daily slurry volumes to be digested and bio fertilizer storage volume was calculated as to store six month fermented fertilizer based on 180 days total slurry volume (Table 5). Floor areas and elevations of proposed biogas facilities are provided in Table 6.

Table 5. Pretreatment tank and bio fertilizer storage volumes

Number of livestock	DTSV (m^3)	Pretreatment tank (m^3)	Bio fertilizer tank (m^3)
250	10	10	1 800
500	20	20	3 600
1 000	40	40	7 200

DTSV: Daily Total Slurry Volume

Area and elevations for pilot facilities are provided in Table 6. Floor area of facilities planned for 250, 500 and 1 000 bovine manure capacities were respectively calculated as 41 m^2, 66 m^2 and 104 m^2; elevation from the floor including gas tank were respectively calculated as 11.00 m, 13.90 m and 17.45 m.

The floor plans, cross-section and side views of a pilot biogas facility designed for 250 ovine manure capacity are presented in Figure 1.

Table 6. Floor areas and elevations of proposed facilities

Number of livestock	Floor area (m^2)	Surface area (m^2)	Elevation (m)
250	41.39	165.35	11.00
500	65.89	263.30	13.90
1 000	103.86	415.47	17.45

Type of biogas facility was determined by considering strong and week points of various alternatives. Floating balloon type biogas facilities were preferred in this study because of resistance, design cost, easy design, reliability, gas tightness, security, easy transport, operation and maintenance. Steel profiles are used as construction material of the facilities because of easy transport, construction and easy integration into mixing system.

Conclusion

Livestock manure is stored open fields and creates various problems on environment in Tokat Province. Besides being used over the agricultural lands as fertilizer, manure is also used for heating and cooking in rural parts of the province. When the manure is used for heating purposes, sufficient heat is not produced and post-burning residues are not able to be used as fertilizer. Energy obtained from direct burning is relatively lower than the energy obtained through conversion of manure into biogas. Using manure over agricultural fields is also more economical than converting it to energy through direct burning. On the other hand, fermented fertilizer from the biogas facilities to be designed is more beneficial for soil and has a potential to reduce chemical fertilizer use over agricultural lands.

Biogas use in heating and cooking purposes is found to be beneficial in Tokat Province. The greatest obstacle in front of widespread of biogas facilities in rural sections is not to provide end users with technical, economic and socially sustainable facilities. Livestock and plant waste potentials and geographical locations should be taken into consideration in biogas facility design for rural parts of the country. Considering the climate and production conditions, low-cost, high-yield, easily constructed, operated and maintained systems should be designed and constructed.

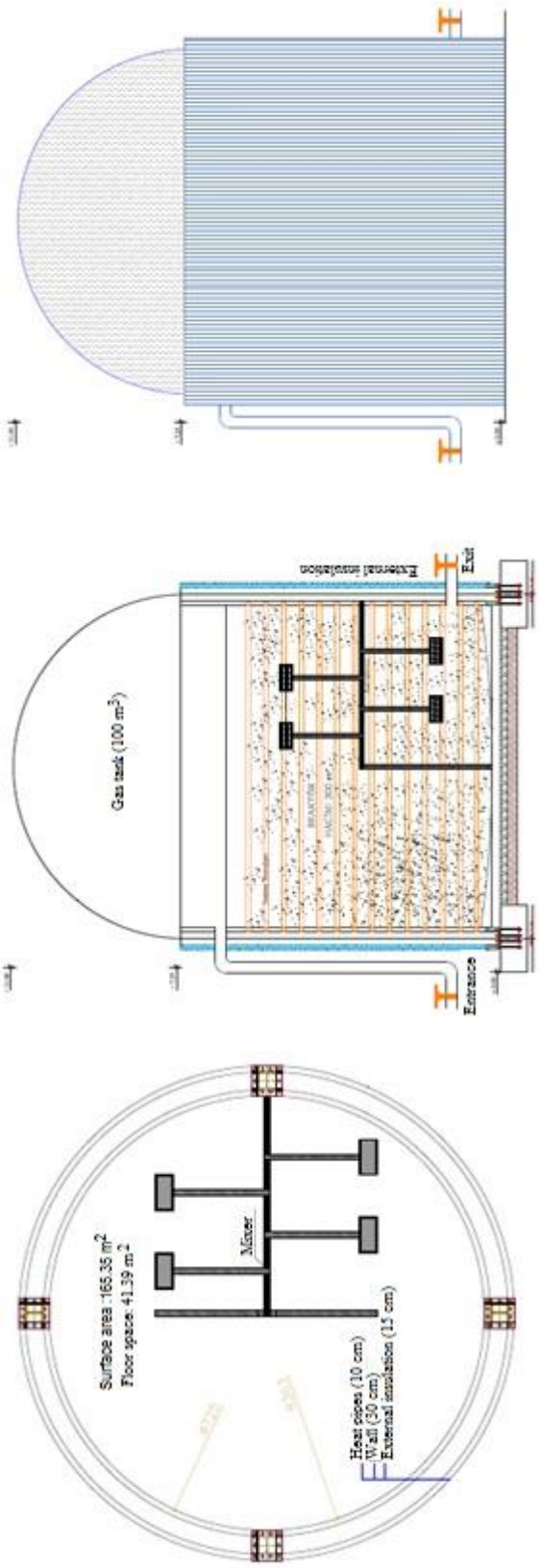

Figure 1. Floor plan, cross-section and side view of pilot facility designed for 250 bovine manure capacity (Scale: 1/200)

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