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Biogas Production Potential from Animal Manure of Bursa Province

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Abstract: Agricultural operations and livestock production are among the important economic activities for Turkey. But the great majority of energy demand of the agricultural enterprises is still supplied by conventional energy sources. The environment friendly biogas production which reduces the production costs in agricultural enterprises, is becoming more and more important. Animal manure, energy plants and agricultural organic wastes can be used as sources of biogas in the farms. The aim of this study was to determine the biogas production potential of Bursa for the period of 2008-2014. Chicken waste biogas potential production in 2008 took the first place with 54.612 dam^3 and the total potential of biogas in 2014 increased to 129.106 dam^3 by 33% compared to 2008. The amount of biogas in the case of 50% and 25% use of the theoretical biogas potential were calculated to be 64.553 and 32.276 dam^3 in 2014, respectively. The heat and electrical energy equivalents of the biogas were found to be 2.788 TJ and 271 GWh_e, respectively. In the other two scenarios, i,e. for 50% and 25% use of the theoretical biogas potential, heat and electric power values were determined proportionally.

Key Words: Bursa, biogas, animal waste, energy.

Bursa İlinde Hayvansal Atıklardan Biyogaz Üretim Potansiyeli

Özet: Tarım ve hayvancılık ülkemiz için önemli ekonomik faaliyetler arasında yer almaktadır. Fakat tarımsal işletmelerin enerji ihtiyacının çok büyük bir bölümü halen konvansiyonel enerji kaynakları ile karşılanmaktadır. Tarımsal işletmelerde enerji ihtiyacının karşılanmasında çevre dostu olan, üretim girdilerini düşüren biyogaz eldesi ve kullanımı önem kazanmaktadır. Tarımsal işletmelerde biyogaz kaynağı olarak hayvan gübresi, çeşitli enerji bitkileri ve tarımsal organik atıklar kullanılabilir. Bu çalışma, Bursa ili 2008-2014 yılları için hayvan gübresinden biyogaz üretim potansiyelini belirlemek amacıyla yapılmıştır. 2008 yılı tavuk atıklarından biyogaz üretimi 54.612 dam^3 ile birinci sırada yer alırken, 2014 yılı toplam biyogaz potansiyeli 2008 yılına göre %33 oranında artarak 129.106 dam^3olmuştur.Teorik potansiyelin %50'sinin kullanılması durumunda 2014 yılı biyogaz miktarı 64.553 dam^3, %25'inin kullanılması durumunda ise 32.276 dam^3olarak hesaplanmıştır. Bursa ili 2014 yılı verilerine göre 2.788 TJ ısıl enerji ve 271 GWh_e elektrik enerjisi elde edilebilmektedir. Diğer iki senaryoda (%50 ve %25 oranlarında) ise teorik potansiyelden yararlanma oranına bağlı olarak elde edilebilecek ısı ve elektrik enerjisi değerleri oransal olarak belirlenmiştir.

Anahtar Kelimeler: Bursa, biyogaz, hayvansal atık, enerji.

Introduction

Energy demand around the world has been increasing due to reasons such as industrial development and population growth. Meeting this energy demand with fossil fuels increases CO_2 emission, resulting in environment and air pollution and global warming (Chang et al., 2003). In addition, in today's world, where conventional energy reserves have gradually been depleted, energy has been one of the most expensive production inputs. For this reason, demand for environmentally-friendly, renewable energy sources has increased and thus the advancement in renewable energy sources has gained an impetus (Klaassenet al., 2005). Besides nuclear energy, forms of energy such as geothermal, solar, wind and biomass (biogas, biodiesel and biologic mass energies) which are termed as new and clean energy sources, have gained importance and many of these forms of energy have been economically used in recent years.

Biogas is a form of gas produced by the biochemical fermentation of organic material under anaerobic conditions. It is inflammable, colorless, odorless, and lighter than air with an octane rating of 110. It burns with a bright blue flame and is primarily composed of methane and carbon-dioxide (Alibaş, 1996; Bilgin, 2003; Koçaret al., 2007; Yaldız, 2009).

Similar to many other fields, increasing energy costs have made renewable energy sources more economical and thus preferable in agriculture sector. Storage and discharge of animal waste is one of the most important problems of agricultural enterprises. Biogas production at farm scale through anaerobic fermentation refers to stabilization of animal waste in order to produce domestic fuel and to use fermented animal manure as fertilizer (Alvarez and Liden, 2009). In agriculture sector in Turkey, where energy need is mainly met by primary energy sources, production and utilization of environmentally-friendly biogas, which reduces production inputs, gains significant importance to meet energy needs.

The objective of this study was to determine the biogas production potential of Bursa province for cattle, poultry, and sheep-goat wastes. Bursa province is one of the most important areas in agricultural production and animal production in the country.

Material and Method

Number of cattle, small ruminant, equidae and poultry animals in Bursa province in 2008-2014 period was obtained from Turkish Statistics Institute (TSI). Amount of daily produced manure varies according to animal species. Furthermore, length of stay in the shelter affects amount of collectable manure. While almost all manure can be collected in poultry depending on the length of stay in the shelter, amount of collectible manure is lower in feeder cattle, sheep and goats. In this study, the cattles were classified as calf and mature animal, according to the TSI data, and the corresponding manure amounts were determined based on this age classification. Length of stay in the shelter for cattle was taken as 100%

as the relatively larger enterprises are concentrated in western part of Turkey and the animals are kept in shelters rather than grazing in pastures. Length of stay in the shelter of some animals and solid matter contents of manures are presented in Table 1. In calculations, mean live weights were taken to be 500 kg for cattle, 50 kg for small ruminant, 2 kg for hens, 8 kg for other poultry animals, 250 gr for equidae and 400 kg for horses (Alçiçekand Demiruluş, 1994; Alibaş, 1996; Eliçinet al., 2014; Karaman, 2006; Koçeret al., 2006).

Table 1. Time spent ratio in the shelter andsolid matter content of the organic waste can be obtained from various animals (Aktaşet al., 2015; Alibaş, 1996; DBZF, 2011; Eliçinet al., 2014; Kaya and Öztürk, 2012)

Animal type	**Time spent in the shelter (%)**	**Solid matter content (%)**
Mature cattle	100,00	15,00
Calf	100,00	15,00
Meat hen	99,00	40,00
Egg hen	99,00	40,00
Turkey	68,00	25,00
Sheep, Goat	13,00	25,00
Horse	29,00	20,00

The following equations were used to calculate biogas potentials and the corresponding energy values. The total amount of manure that can be produced by the animals per day was determined by equation 1.

$$M_{Dw} = M_w \times T_S \quad (1)$$

where 'M_{Dw}' is obtainabledaily total manure per head (kg/day-head), 'M_w' is wet baseddaily total manure per head (kg/day-head) and 'T_S' is the length of stay in the shelter of animals (%).The amount of biogas that can be produced was obtained using equation 2.

$$B_A = M_{Dw} \times P_L \times C_b \times 0{,}365 \quad (2)$$

where 'B_A' is annual amount of biogas (m^3/a), 'P_L' is livestock population and 'C_b' is biogas coefficient which was determined by animal type and biogas amount in m^3/t. Dry matter contents of cattle, small ruminant, and poultry manures were assumed to be$\leq$ 15%, $\leq$ 25% and $\leq$ 40%, respectively. Manures of small ruminants and hen have significantly higher biogas potential than cattle manure due to dry matter content, protein content, and raw material properties (Akbulutand Dikici, 2004; FNR, 2010; Kaya et al., 2009; Kaya and Öztürk, 2012). Equation 3 was used to calculate the calorific energy value of biogas.

$$B_T = C_c \times B_A \quad (3)$$

where "B_T" is equivalent calorific energy of biogas (MJ) and 'C_c' is calorific coefficient determined by the rate of methane in the biogas (MJ/m^3). Although calorific value of biogas varies according to its methane content, it is approximately 20-27 MJ/m^3 (Alibaş, 1996; Anonim, 2014; Banks, 2014; Eryaşarand Koçar, 2009; Frost and Gilkinson, 2010; Gümüşçüand Uyanık, 2004; Kaya and Öztürk, 2012).

Equivalentelectrical energy varies according to the methane content of biogas and electrical conversion efficiency (Anonim, 2012; Astalsand Mata, 2011; Banks, 2014; DBZF, 2011; Kaya and Öztürk, 2012). In this study, methane content of biogas and conversion efficiencyto electricity weretaken to be 60% and 35%respectively. The equivalent electrical energy value of biogaswas determined using equation 4.

$$B_E = C_e \times B_A \tag{4}$$

where "B_E" is equivalent electrical energy value of biogas (kWh_e) and 'C_e' is electrical coefficient determined by the rate of methane in the biogas and conversion efficiency to electricity (kWh_e/m^3).

Results and Discussion

The obtainable manure calculated based on animal holding in Bursa province and numbers of animals are presented in Table 2. According to TSI data, animal holding in Bursa province increased 48% in 2014 compared to 2008. In parallel to this increase in animal holding, obtainable manure increased 31% in 2014 compared to 2008, reaching 2.679.038 tons. Analysis of animal holding in Bursa province in 2014 revealed that poultry animals had the largest share (92%) in terms of animal holdings, while cattle waste had the largest share (78%) in terms of animal waste.

Table 2. Total manure production levels in Bursa between 2008-2014

	Total Manure Production (t)							
Year	**Mature Cattle**	**Calf**	**Sheep**	**Goat**	**Meat Hen**	**Egg Hen**	**Turkey**	**Horse**
2008	1.493.758	130.728	20.462	5.183	305.743	84.344	679	4.562
2009	1.586.915	114.561	22.867	5.016	276.160	85.755	792	4.854
2010	1.653.176	135.329	24.744	6.557	250.035	90.328	381	5.106
2011	1.707.694	165.391	26.628	9.105	288.609	174.606	316	4.729
2012	1.862.486	184.252	31.037	9.197	303.572	196.386	5.332	4.156
2013	1.972.862	191.460	31.781	10.166	312.859	179.627	7.418	4.164
2014	1.927.816	179.469	33.789	10.372	334.450	193.142	10.152	4.177

Biogas potential was calculated according to animal waste potential of Bursa province and calorific energy value and electrical energy values that can be obtained from this potential were presented in Table 3. Utilization ratio from animal waste for biogas production showed variations depending on various factors such as enterprise structure, storage of waste, and transportation. Three scenarios were developed in calculations including the use of 100% (theoretical potential), 50% and 25% of animal waste potential in Bursa province.

Table 3. Biogas, calorific energy and electrical energy potential of Bursa between 2008-2014 based on 100, 50, and 25% use of the total manure

		Biogas Potential			Calorific Energy of Biogas			Electrical Energy Potential of Biogas		
		(dam^3)			(TJ)			(GWh_e)		
		100%	**50%**	**25%**	**100%**	**50%**	**25%**	**100%**	**50%**	**25%**
2008	**Cattle**	40.612	20.306	10.153	877	439	219	85	43	21
	Sheep-Goat	1.487	744	372	32	16	8	3	2	1
	Chicken	54.612	27.306	13.653	1.180	590	295	115	57	29
	Total	96.712	48.356	24.178	2.089	1.044	522	203	102	51
2009	**Cattle**	42.537	21.268	10.634	919	459	230	89	45	22
	Sheep-Goat	1.617	809	404	35	17	9	3	2	1
	Chicken	50.668	25.334	12.667	1.094	547	274	106	53	27
	Total	94.822	47.411	23.706	2.048	1.024	512	199	100	50
2010	**Cattle**	44.713	22.356	11.178	966	483	241	94	47	23
	Sheep-Goat	1.815	908	454	39	20	10	4	2	1
	Chicken	47.651	23.825	11.913	1.029	515	257	100	50	25
	Total	94.179	47.089	23.545	2.034	1.017	509	198	99	49
2011	**Cattle**	46.827	23.414	11.707	1.011	506	253	98	49	25
	Sheep-Goat	2.073	1.036	518	45	22	11	4	2	1
	Chicken	64.850	32.425	16.213	1.401	700	350	136	68	34
	Total	113.750	56.875	28.437	2.457	1.228	614	239	119	60
2012	**Cattle**	51.168	25.584	12.792	1.105	553	276	107	54	27
	Sheep-Goat	2.334	1.167	583	50	25	13	5	2	1
	Chicken	69.994	34.997	17.499	1.512	756	378	147	73	37
	Total	123.496	61.748	30.874	2.668	1.334	667	259	130	65
2013	**Cattle**	54.108	27.054	13.527	1.169	584	292	114	57	28
	Sheep-Goat	2.433	1.216	608	53	26	13	5	3	1
	Chicken	68.948	34.474	17.237	1.489	745	372	145	72	36
	Total	125.489	62.744	31.372	2.711	1.355	678	264	132	66
2014	**Cattle**	52.682	26.341	13.171	1.138	569	284	111	55	28
	Sheep-Goat	2.561	1.281	640	55	28	14	5	3	1
	Chicken	73.863	36.931	18.466	1.595	798	399	155	78	39
	Total	129.106	64.553	32.277	2.789	1.394	697	271	136	68

Analysis of biogas production from animal waste in 2008 showed that the highest amount of biogas could be produced from hen waste (54.612 dam^3) followed by cattle waste (40.612 dam^3) and sheep and goat waste (1.487 dam^3). Similarly, the highest potential in biogas production was obtained from hen waste in 2014, which was followed by cattle and sheep-goat waste. Despite a 44% increase in cattle, sheep, goat and holdings of hen in 2014, total biogas potential increased 33% compared to 2008 with 129.106 dam^3. Biogas potential in 2014 was 64.553 dam^3 and 32.276 dam^3 when 50% and 25% of the theoretical potential was used respectively.

Thermal energy value for 2014 was found to be 2.788 TJ, according to theoretical biogas potential of animal wastes. Calculations according to the assumptions in electric production from biogas showed that 271 GWh_e electrical energycould be produced if all biogas potential was used. As for the other two scenarios, thermal and electrical energy values that could be obtained were determined proportionally depending on the utilization ratio of the oretical potential.

While cattle rearing is generally the common method used the country, poultry rearing is developed in the western part the country. Although both bovine and hen rearing are developed in Bursa province, the existing potential cannot be effectively used in terms of benefitting from biogas production capacity. Considering animal waste potential and agricultural land holding of Bursa province, making biogas facilities widespread, especially in rural areas, will bring economic benefits for the farmers. Very limited investments were made to benefit from biogas in the province. This was due largely to the lack of proper incentives in the biogas production. It is clear that it is not likely to benefit from the theoretical biogas capacity. However, much lower proportions of the theoretical potential can be targeted. For instance, even with 25% use of the biogas potential, significant amount of energy could be generated in the province (Table 3). Electical energy potential was about 50 GWh_e in 2008 and 2009 whereas it increased to about 68 GWh_e in 2014 (Table 3). The amount of manure, and hence the potential for biogas and electricity production may increase further given the trend in manure production from 2008 and 2014. Within this scope, the biogas production should be considered one of the most important means of utilizing the manure in the region. Furthermore, production and utilization of biogas is an environmentally-friendly method and is a strong candidate in meeting therural energy need. Awareness of public institutions and private sector should be raised and investments should be further promoted to benefit from this biogas potential, which is an environmentally-friendly, renewable energy source, at maximum level.

Conclusion

This study determined animal waste biogas potential of Bursa province and calorific and electrical energy values that can be obtained from this potential. In 2014, total amount of animal waste was 2.679.038 ton, which corresponds to a theoretical biogas amount of 129.106 dam^3, and can produce 2.788 TJ and 271 GWh_e calorific and electrical energy, respectively. However, this potential is notused due to the lack of investments. This study showed that manure production increased from 2008 to 2014 and should be expected to increase in the near future. Not all manure could be used for biogas production, however utilizing $1/4^{th}$ of the biogas potential could be an important input to meet the energy need in the rural sector.

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