

Article

Waste Management in Dairy Cattle Farms in Aydın Region. Potential of Energy Application

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Abstract: In this paper, the dairy cattle waste management systems on farms in Aydın region in Turkey were investigated. Number of farms and livestock herd size, type of barn, type of machinery and farm labour force were studied. The collection, management and storage systems of manure produced in dairy cattle farms were taken into consideration. Additionally, biogas amount, which is produced from animal waste, was calculated for all districts of Aydın by using the number of livestock animals and various criteria such as the rate of dry matter. Results show that the typical and representative farm in the Aydın region is facility with a total head over 100 heads. 89.6% of the farms have heads in the range of 100 to 200. The amount of biogas that can be produced from all manure collected in Aydın region in the biogas plants is approximately 160,438 m³/day (based on 0.5 m³/day biogas per cattle), which would produce around 100 GWh/year that can be used for own needs of farms owners.

Keywords: animal waste; biogas; dairy cattle farms; energy potential; waste management

1. Introduction

Nowadays, expansion and intensification of large-scale animal feeding operations has resulted in an increase in the size of farms and in the amount of waste produced from farms causing serious problems such as a negative impact on environment and public health in rural areas.

By the end of 2014, according to FAOSTAT [1], 24.99 billion animals were produced on farms all over the World. The livestock sector is one of the fastest growing parts of the agricultural economy. In recent years there has been an increasing demand for cattle production. The large cattle producers are Brazil about 218 million, India 186 million and China 83 million heads [1].

In Turkey, the greatest livestock production belongs to cattle farms, with about 17 million heads of cattle being bred in 2018, resulting in an increase of 33% compared to 2010. Dairy cattle produced about 22 million tonnes of milk and 1 million tonnes of meat in 2018 [2]. Table 1 presents the total amount of animal production from species across years in Turkey.

The breeding and agricultural activities, especially livestock production on an industrial scale, are seen as one of the main sources of natural environment pollution [3,4]. Depending on the farming system, animal farms generate solid (dung) and liquid (liquid manure) animal excrement. In this day and age, no-mulch systems are becoming more and more popular, particularly for livestock production on a large scale. The excrement in this system is so-called liquid manure, i.e., liquid, or a semiliquid mixture of faeces, urine, water and feed leftovers.

Table 1. Total amount of animal production in Turkey by species [1].

Animal	Unit	2008	2010	2012	2014
Buffaloes	Head	84,705	87,207	107,435	121,826
Camels	Head	1057	1041	1315	1442
Cattle	Head	11,036,753	10,723,958	13,914,912	14,223,109
Sheep	Head	25,462,292	21,794,508	27,425,233	31,140,244
Chickens	Head ×1000	269,368	229,969	253,712	293,728
Goats	Head ×1000	6,286,358	5,128,285	8,357,286	10,344,936
Turkeys	Head ×1000	2675	2755	2761	2990

It is estimated that the cattle residues produced in Turkey reached the value of 1.3×10^6 tonnes/year in 2012 [5]. The amount of wet manure from animals could be a major problem for farms. If the wet manure cannot be utilized properly, it can create pollution risk with a potentially disastrous impact on the environment.

Manure management depends on many factors such as the size of the herd and type of manure, as well as available labour, soil type, climate and region [6,7]. Additionally, intensive animal production can be significantly problematic with respect to manure storage and removal [3].

Effluents of improperly stored manure can flow directly or indirectly into surface waters in open lagoons. As a result, gaseous emissions and odours can also be released upon decomposition of manure, with negative consequences for farmers' fields and livestock farms [8,9]. Fanguero [10] reported that greenhouse gas (NH_3 , N_2O , CH_4) emissions during storing depend on type of manure, i.e., emission from separated solids, are typically higher than from liquid or unseparated manure. Animal manure contains a wide range of micro-organisms which could be a source of hazards to humans and animals. These micro-organisms can cause food contamination and epidemics and are dangerous to public health [3,11]. Therefore, sustainable manure management systems on farms must minimize risks for the environment associated with storage, handling and utilization of manure.

Animal manure contains essential nutrients such as nitrogen, phosphorus, potassium and can be applied to land as a natural fertilizer [7,8], which is the most common method of manure application. Organic matter improves the physical and biological properties of soil, as well as aeration and soil water infiltration [12].

However, in recent years, we have observed a large problem of environmental pollution caused by nitrates connected with irrational use of natural fertilizers in agriculture [13,14]. The manure contains large amount of N in organic form and converted to inorganic form through mineralization process which is ultimately a serious risk to the environment. Manure is applied to the soil at one time (usually by spreading out on the field), so more leaching occurs as compared to chemical fertilizer and the N content may reach the ground and surface waters [15].

Animal manure can also be used as substrate for biogas production in the process anaerobic digestion [16–18]. Biogas is a product of methane fermentation of organic fraction of many types of biomass.

The methane fermentation process consists of four phases (hydrolysis, acidogenesis, acetogenesis and methanogenesis) [19]. The main stages of anaerobic digestion are presented in Figure 1.

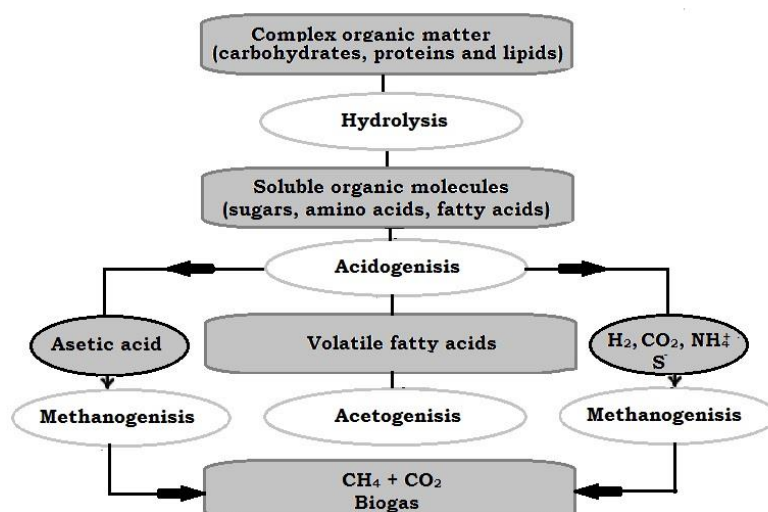


Figure 1. Stages of anaerobic digestion (methane fermentation process) [20].

The composition of biogas is different and depends on the applied substrates; however, typically it consists mostly of CH₄ (40%–70%) and CO₂ (15%–60%), as well as other compounds in small amounts: H₂O (2%–7%), N₂ (2%–5%), O₂ (0%–2%) < 1% H₂, NH₃ (0%–1%) and H₂S (0.005%–2%) [8,21].

In the process of biochemical transformations in the absence of oxygen instead of biogas is also produces the nutrient rich organic fertilizer which is easy assimilated by the plants, with a reduction in the odours and the disease-causing agents [19].

The biogas energy potential of Turkey was found to be 2.18 billion m³ based on the animal numbers in the last agricultural census. The total biogas potential originates from 68% cattle, 5% small ruminants, and 27% poultry. The biogas energy equivalence of Turkey is approximately 49 PJ [5]. After comparing the biogas potential for animal manure of Turkey with that for different countries (Germany 20.6 billion m³, Poland 6.4 billion m³, Italy 1.9 billion m³ and Sweden 7.04 billion m³) [22], Turkey has a high biogas potential, which is associated with the increasing production in the livestock sector.

As of now, only 7% of this potential is used. There are 19 biogas power plants that produce electricity from animal manure in Turkey. The total installed power capacity of the biogas power plants is 43.41 MW_e. The range of the installed power capacity is from 0.33 to 6.40 MW_e [23].

The collection, storage and utilization of animal manure are the major problems for local livestock farmers. Problems and strategies with respect to manure management should be taken care of on a local scale and adapted to the existing conditions in a given area. There are several studies focused on cattle in Turkey [24–27]. However, region-based studies are few and limited [28,29].

The aim of this study was to investigate the collection and management of manure in the cattle farms in Aydın region. Number of farms, livestock herd size, type of barns, type of machinery for collecting manure, farm labour force and manure management were also studied to evaluate the possibility of using manure as a feedstock for biogas production for energy generation.

2. Materials and Methods

2.1. Study Area

Aydın province is located in Aegean Region of western Turkey (Figure 2). The Aegean Region has a typical Mediterranean climate with hot-dry summer and warm-rainy winter. The average annual temperature is 17.6 °C, 26.77 °C in summer and 9.33 °C in winter.



Figure 2. Turkey and Aydın province [30].

The relative humidity of the air is between 48% and 55% and the average rainfall is on the level of 647 mm [31].

The area of Aydın province with 17 districts is 8007 km². The population was 1,097,746 with density of 140 people/km² in 2018. The cultivated area is about 395,494 ha corresponding to 49.3% of soil sources of Aydın and 75,000 ha of cultivated area is used for cereal production. The main agricultural products in Aydın province are fig, olive, chestnut, cotton and fruits [32].

2.2. Methods

The aim of this study was to investigate manure collection and management in cattle farms in the Aydın region of Turkey and determine the energy potential of the waste generated on farms.

In this study, a survey was conducted by interviewing the owners of 87 farms located in 17 districts of Aydın province and each farm was photographically documented.

The survey included general topics presented below:

- education level of farmers and the possibility of using new technologies,
- livestock herd size,
- type of barns,
- type of machinery for collecting manure,
- manure storage systems,
- methods of manure application.

In addition, the energy parameters of manure waste as a potential substrate for the biogas production were also examined. The tests were carried out in accordance with the following standards:

- moisture—EN ISO 18134:2015,
- ash—EN ISO 18122:2015,
- organic matter—EN 12176:2004,
- high heating value (HHV)—EN 14918:2009, ISO 18125:2015 using IKA C 5000 Calorimeter,
- elementary analysis (C, H, N, S, O)—EN ISO 16948:2015 using Elementary Vario Macro Cube analyser.

Based on the data obtained from 87 farms livestock size in the study region, potential of biogas and electricity production were calculated using equation 1 and 2 below:

Biogas production (BP) [33]:

$$BP = N_c \times C, \quad (1)$$

where: N_c —the number of cattle, C —production of manure per day/cattle (on the basis of an assumption of 0.4 m³/day/cattle [34].

Electricity production (EP) [21]:

$$EP = BP \times LHV \times \%CH_4, \quad (2)$$

where: %CH₄—methane content in the biogas (on the basis of an assumption it is 62%), LHV_{CH₄}—low heating value of methane (21 MJ/m³)—1.7 kWh in cogeneration process: 1.7 kWh electricity and 2 kWh heat) [34].

3. Results and Discussion

In Aydın province, many of farms are located in the districts: Efeler (18 farms), Cine and Kuyucak (12 farms) and Söke (10 farms). Table 2 presents number of cattle in districts of Aydın.

Table 2. Total amount of cattle in Aydın’s districts [35].

Aydın’s Districts	Number of Cattle, Head
Efeler	34,300
Bozdoğan	26,244
Buharkent	2025
Çine	62,376
Didim	3047
Germencik	19,144
İncirliova	9048
Karacasu	10,219
Karpuzlu	27,027
Koçarlı	23,953
Köşk	8757
Kuşadası	1283
Kuyucak	21,713
Nazilli	26,000
Söke	24,145
Sultanhisar	4595
Yenipazar	17,000
Total	320,876

Farms in Aydın province usually have more than 100 cattle and the number of animals in the 89.6% of the farms range between 100 and 200 heads.

The study shows that 69.55% of the farmers are under age 50. The ages of the youngest and oldest farmers are 28 and 74, respectively. The percentage of owners who have a university degree was 14.9%, whereas most of the owners have an elementary school degree (43.7%). Only farmers with higher education showed an interest in application of new technologies.

Manure storage type is of importance in terms of impacts on gaseous emissions and the flexibility it offers for land application and hence the potential for nutrient losses to ground and surface waters.

Generally, owners of farms have noticed the problem of disposal of manure, the facility must minimize the impact on water quality, especially on groundwater and surface water. It is indicated that the manure storage facility should be located at least 100 m away from the water resources [36].

In the Aydın region, the distance between open-air manure storage and water resources, as well as source of drinking water supplies, is 96 m on average. Çayır and Atılğan [37] examined about 74 farms in Burdur province and determined the distances to be 1–10 m in 39 farms, 11–20 m in 20 farms and 21–30 m in 10 farms, and 31 m or more in 5 of 74 farms. According to Mutlu [38], Jacopson et al. [39] and Nizam et al. [40], this distance should be much longer.

In the study area, manure storage facilities are located in the open area. The most common type of manure storage is midden (60%), and 30% and 10.3% of farms store the manure on flat ground and on leak-proof pits, respectively. Figure 3 presents the types of manure storage used in Aydın region. Manure stored on flat ground is shown in Figure 4.

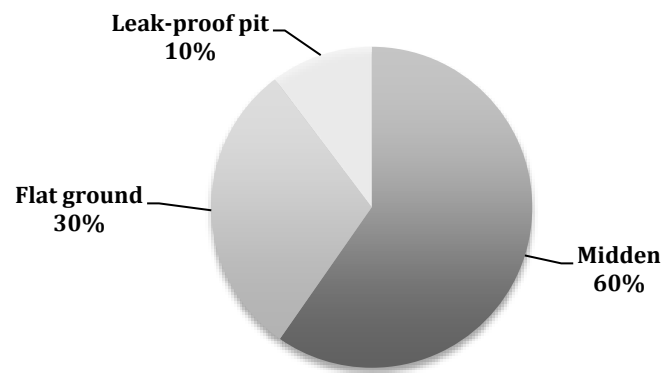


Figure 3. Types of storage used in Aydın region.



Figure 4. Manure storage on flat ground.

Study shows that 66.6% of farms do not have manure storage pits on protected ground (concrete floor). Therefore, there is a danger of contamination of ground water with nitrogen compounds.

For example, according to the survey by Smith et al. [6], manure is stored in concrete floor compounds (40%) and temporary field heaps (60%) in England. Loyon [41] stated that 23% of facilities for storing manure are covered in France.

Manure is usually stored for many months, and during its decomposition, manure emits unpleasant gases such as ammonia and hydrogen sulphide and impacts the health and comfort of surrounding people. Another problem is to minimize odour from manure storage locations as well as from open barns, which depends on the size of the intensive livestock operation, the type of livestock or manure management system and storage time.

The results of this study show that 48.2% of farms have closed-wall barns, 41.4% semi-open barns and rest of them have open sheltered barns. Semi-open barns are shown in Figure 5.

The conventional method of handling manure has been to use sufficient bedding to keep the manure relatively dry and then to move it out of the confinement area and deposit it into a manure pile [42].

In large production units, manure is handled both mechanically and hydraulically. Mechanical removal of the wastes is normally done with tractors, manure spreaders or scrapers with permanently installed equipment, such as shuttle conveyors, floor augers or pumps.

The information collected from the dairy farms assessed in this study showed that 67.8% of the farms used tractor shovels for the collection of manure produced in barns. The percentage of manual collection was 14.9%, and there were only 9 farms (10.4% of the farms evaluated) in which the manure was collected with scrapers equipped with chain. 89.7% of the farms do not have any impermeable manure pits.



Figure 5. Semi-open barns.

The most common waste management strategy on farms is to apply the manure to the land. Atılğan et al. [43] divided it according to content of solids, i.e., above 25% solid fertilizer; 10–20% semi-solid and 0–10% content of soils is called liquid manure. All produced manure in the studied farms is used in agriculture as fertilizer, mostly for their own purposes, and only 12.6% of farms sell it. The studied farms utilize only the solid manure, which provides minimum benefit because of the loss of organic nitrogen content during long storage, while it can also cause serious environmental pollution.

It is stated that the main source of nitrate contamination in groundwater is agricultural fertilizers.

In the Aydın region the high level of nitrite (0–124 mg/L) [44] in groundwater used for the irrigation was noted. The average level of nitrite in the surface water is in the range of 0.01–0.7 mg/L, nitrate 1.20–3.70 mg/L, ammonia 0.04–5.20 mg/L [45]. According to the World Health Organization (WHO) [46], the standard nitrate level in drinking water is 50 mg/L. Groundwater is used as irrigation (from 8–32 m deep) and drinking (>32 m deep). Elevated nitrate concentrations in groundwater can cause public health problems. Now Turkey has updated regulations aiming to combat agricultural nitrate pollution in rivers and soil. The revised rules include procedures and principles for determining, reducing and eliminating nitrate pollution [47].

Due to the increase in the Turkish population, and therefore the increase in demand from the animal sector, contamination from pollutants may also cumulatively increase in the next years. Regulations are required in order to control manure management, especially the localization of manure storage and type of floor construction for its temporary storage, as well as the limits for the use of manure as fertilizer.

Baytekin [33] claims that, under normal conditions, a healthy cow produces 40–45 kg of manure per day. According to this value, the total manure amount obtained from the research area is as presented in Table 3.

Table 3. Total amount of produced manure in farms.

Production of Manure *	Daily Tonnes	Weekly Tonnes	Monthly Tonnes	Annual Tonnes
	13,637	95,460	409,116	4,977,588

* calculated from obtained data.

The production of biogas from manure, in particular, is one of the alternative utilization methods of organic wastes that can be implemented in this region. This study also attempts to identify the biogas potential of the Aydın region basing on obtained data of animal manure production.

As a first step for this application, the energy parameters of manure, as a potential feedstock for the biogas production were tested. Obtained energy parameters of manure is presented in Table 4.

Table 4. Energy properties of manure.

Parameter	Moisture % wt	Dry mass % wt	Ash %wt	Organic Matter %wt	C % dm	H % dm	N % dm	S % dm	O * % dm	HHV MJ/kg
Value	79.9	20.1	11.50	74.62	48.09	7.13	2.14	0.27	42.66	16.48

wt—weight percentage; dm—dry mass; HHV—High Heating Value; *—calculated on the basis of the obtained difference.

One of the key parameters in terms of the efficiency of biogas production is associated with the high content of organic matter in wastes, and this determines the course of the fermentation process and the volume of the biogas [21]. The tested samples have a high content of organic matter (74.62%), which is comparable with data obtained by Zue et al. [48], it may range from 68% to 76%. For methane fermentation, especially for the growth of microorganisms, one of the important factors is the ratio of C:N (optimum 20–30:1) [49]. The ratio of C:N in the waste (24:1) is adequate in this respect.

For the Aydın province, based on the amount of produced waste, it is possible to obtain about 160,438 m³ biogas/day, assuming 0.5 m³/day biogas per cattle. Table 5 contains total amount of produced biogas in Aydın and LPG equivalent.

Table 5. Total amount of produced waste and biogas in Aydın and its LPG equivalent.

Production of Biogas *	Daily m ³	Weekly m ³	Monthly m ³	Annual m ³	Equivalent of LPG m ³ /year
	160,438	1,123,066	4,813,140	58,559,870	93,895,792

* calculated from obtained data.

It gives production of electricity on level 99,552 MWh annually. In Aydın in 2012 electricity consumption was 1,860,667 MWh. In the case of the use of biogas, which can be substituted for conventional fuels, 5.4% of electricity can be covered by biogas.

There is only one biogas power plant—Efeler BGEPP—in the Aydın region, with a max installed power of 4.8 MW_e. Because of the distributed allocation of small-capacity livestock farms in the region, and also due to the low interest of farmers in installing their own small biogas installations, it is proposed to build centralized facilities.

Considering the use of only half of the manure generated in the region, it is possible to install 7 biogas power plants with a capacity 4.8 MW_e in different locations. Because of the topography and the distances between farm locations, the Aydın region can be divided into four districts, in which 3–4 biogas power plants can be installed with capacities similar to the Efeler BGEPP facility.

There are some funds that support investments in renewable energy sources in Turkey such as: *Renewable Energy Resources Support Mechanism (YEKDEM)*, coordinated by the Energy and Natural Resources Ministry, the regional scale *Agriculture and Rural Development Support Institution (TKDK)*, supported by the Agriculture and Forestry Ministry, and also local development agencies subordinate to the Ministry of Development, for example, the South Aegean Development Agency (GEKA) serving, i.a., the Aydın region.

According to the Turkish National Energy and Mining Strategy, it is a top priority for Turkey to generate 30% of its electricity from local and renewable resources by 2023. The costs of achieving this target by 2023 are estimated to require investment in renewable energy generation of around 21 billion USD (1.5 billion USD/year) [50]. In the case of Turkey, which is a net energy importer, 73% of its energy needs come from foreign suppliers, and investments in a local and secure energy supply is main pillar of the energy sector.

Biogas, biomass, and geothermal energy resources are expected to comprise a considerable part of RES with the rapid growth in utilization of these resources in the market [51].

Biogas can be used for heating and electricity production, providing local autonomy for the region in the face of the increasing cost of fossil fuels.

Manure storage facilities on farms should be considered to be a temporary solution, and farmers should have knowledge about the negative influence on the environment caused by improper treatment of manure. Education and financial support in changing the approach to animal waste management can be a key factor.

The conversion of animal waste to biogas through anaerobic digestion processes can provide added value to manure as an energy resource and reduce the environmental problems associated with animal waste. It is worth mentioning that dairy cattle manure is endowed with considerable biogas production, offering numerous benefits with respect to environmental, agricultural and socio-economic standards.

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