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Research Article

Assessment of the Energy Potential of Chicken Manure in Türkiye

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Abstract: Biomass-based energy systems have a critical role in the environment, both for supplying electricity demand and disposing of wastes. When waste is not utilized, environmental problems such as providing new waste areas and spreading terrible odors occur. Besides, chicken manure is considered as an abundant renewable source due to the amount of chicken, and it is easy to utilize it to provide waste management while producing heat. Türkiye is Europe's leading poultry producer with a chicken population of over 350 million. The population consists of laying hen and broiler hen. Potential of chicken manure energy can be converted to useful energy through various processes such as direct combustion to produce heat, thermochemical conversions or thermodynamic cycles. This paper aims to determine the theoretical and technical energy potential of chicken manure in Türkiye and the chicken-derived potential biomass energy of Bursa province was presented. The findings demonstrate that the volume of chicken manure was assessed as 13 million tons per year approximately in Türkiye and 0.47 million tons in Bursa province. 44.8% of the total number of poultry animals are raised in the district of Karacabey in Bursa. District of Yenişehir's contribution to the poultry population of Bursa is 15%.

Keywords: Chicken Manure, Livestock, Energy Analysis, Potential Energy, Türkiye.

I. INTRODUCTION

Increasing energy consumption, rapid population growth, and technological developments have increased the need for energy demand day by day. At the point of meeting this need, renewable energy is an important alternative resource that can replace rapidly exhaustible fossil fuels. Biomass is a renewable energy sources besides solar, wind, hydrogen, geothermal. It is mainly used as fuel in combined heat power systems and transformed into electrical energy.

Biomass of various types can be used for heat and power generation as an additive or replacement for coal or oil. Manure is one the most common in biomass types and combustion is one the common method. Turzynski et al. [1] have studied on chicken manure combustion and heat production in terms of thermal self-

sufficiency of a poultry farm. They have reported the heating value of chicken manure as 16.18 MJ/kg. They also emphasized that the characteristics of chicken manure and the experimental results show that it is difficult to burn this fuel alone. As a solution, experimental results have shown that the addition of just 10% of straw or wood improves the combustion process. The generated heat by combustion can be supplied to other processes such as electricity generation or cooling.

Energy and exergy analyses of a biogas driven multigeneration system has been conducted for performance evaluation by Sevinchan et al [2]. The system consists of different subsystems, such as biomass digester, Brayton cycle, Organic Rankine Cycle (ORC), single-effect absorption chiller, heat recovery and water separation unit. The system produces biogas from chicken manure and maize silage, and generates electricity. In the system the maximum electrical power energy efficiency is 40.11%, maximum cooling energy efficiency is 62.18%, and maximum heating energy efficiency is 65.35%.

Sorgulu et al. [3] have developed an organic Rankine cycle (ORC) integrated with a combustion subsystem for organic wastes to energy applications. The organic wastes used for experimental investigation are chicken manure. A novel drying unit is also employed to dry out the chicken manure to the desired moisture level for more efficient and effective combustion. The heat generated is further supplied to the ORC for power generation. Finally, the heat rejected from ORC is used for chicken manure drying purposes. This way, the ORC generates two useful commodities like electricity and heat.

Saka et al. [4] have presented the animal biomass potential of Türkiye in terms of 16 animal species which were classified under three main groups as bovine, small ruminant and poultry. In the study, the chickens have the share of 25% approximately on the overall energy potential among livestock in the countrywide.

Chicken manure management has grabbed significant attention in Morocco due to the increasing demand on chicken and eggs. To evaluate the feasibility of converting chicken manure to biogas in terms of energy gain, the energy balance of the chicken manure for biogas production has been investigated by Chen et al [5]. Experimental analysis of the fixed bed gasification process of the mixtures of the chicken manure with biomass has been done by Tanczuk et al. [6]. The results of the gasification tests confirm that co-gasification of the chicken manure with wood biomass can be a promising proposal for the utilization of a poultry derived wastes.

Tanczuk et al. [7] have aimed to determine the theoretical and technical energy potential of chicken manure in Poland. The volume of chicken manure was assessed as 4.49 million tons per year considering three particular poultry rearing systems. As a treatment option for poultry manure, the production of electricity via fluidized bed combustion has a lower environmental impact than [8]. Poultry manure from all the laying hen farms in Asturias was characterized with a view to its possible use as an energy source by Quiroga et al. [9].

Evaluating the environmental and economic sustainability of energy from anaerobic digestion of different feedstocks in Türkiye has been done by Balcioglu et al [10]. In the study, life cycle assessment and life cycle costing have been carried out for biogas plants utilizing cattle and chicken manure. Varol et al. [11] have investigated the potential of chicken manure to be combusted in a circulating fluidized bed boiler with local lignite. In the study, chicken manure burned in the upper parts of the boiler due to its high volatile matter content and low density compared to coal. Polycyclic aromatic hydrocarbons emissions were found to increase with the increase of the chicken manure share when the chicken manure share was more than 50% by weight. Ersoy and Ugurlu [12] have examined Türkiye's province-based greenhouse gases emissions released by its livestock sector processes. Besides, they have focused on biogas production through anaerobic digestion, which is one of the most effective greenhouse gases mitigation options from manure management. They have reported that Türkiye has great potential in biogas production from animal manures. To show the potential, the biogas potential of animal manure was calculated based on two different scenarios.

Dalkilic and Ugurlu [13] have investigated the biogas production from chicken manure at different organic loading rates, in a mesophilic-thermophilic two stage anaerobic system. The system was operated on semi continuous mode under different organic loading rates. The study has concluded that it is possible to produce high biogas yields from chicken manure at total solid loadings higher than 5%, by using a two stage anaerobic digestion system without using any other carbon rich wastes and without using any chemical additives to control pH.

Türkiye has large livestock population. The number of animal for 16 species was reported from the Turkish Statistical Institute (TurkStat) database, and the corresponding waste production amount based on each species was calculated using the Biomass Energy Potential Atlas (BEPA) of Türkiye [14].

Bursa is one of the crowded cities of Türkiye, and it is located in the Marmara Region. Bursa has seventeen districts and has a great amount of animal production. Saka [15] has investigated the efficiency of a biogas-powered cooling system through the utilization of energy and exergy calculations. The study concludes that a total of 290 head of cattle is required to generate the annual biogas consumption necessary for the cooling system. Additionally, the number of the cattle is enough to establish 284 biogas plants in Bursa Province in Türkiye. There are other power plants in the province where renewable energy sources are used. Saka [16] has investigated the daily, monthly and annual hydrogen generation capacity of a PEM electrolyzer using actual electricity production values of a solar power plant in Bursa.

The amount of biogas energy potential for Türkiye was determined by Avcioğlu and Türker [17]. In the study, for all provinces of country from the number of cattle, small ruminant and poultry by taking into account the various criteria. Also, potential waste map was also developed for Türkiye by them. In the study, available animal waste biogas potential values of provinces in Türkiye according to data in 2009 have been reported. The proportion of poultry in the country's animal waste biogas potential is 27%.

Another study on potential biomass energy for Türkiye has been done by Yılmaz and Saka [18]. They have focused on the exploitable biomass potential of the provinces located in the Southeastern Anatolia region of Türkiye. In the study, the total number of animal in Türkiye is 362,734,882 of which are 28% poultry, 49% small ruminants, and 23% cattle.

In 2022, according to Gülaç [19];

- World chicken meat production was approximately 102 million tons.
- In Türkiye, chicken meat production was 2.4 million tons.

Also she has reported that; there are

- 71 hatcheries,
- 2,403 breeder coops,
- 13,018 broiler coops and
- 4,975 laying hen coops in Türkiye.

In light of the studies mentioned so far, it is understood that chicken manure continues to be an abundant renewable potential energy source in Türkiye. Another point is that biogas production and direct burning are prominent as methods of utilizing chicken manure. Converting chicken manure into biogas is an important way to convert potential energy into usable energy. Using the heat generated by another method, direct burning, is another way to convert potential energy into usable energy. Electricity can be generated from the heat obtained through a cycle, and cooling can also be applied with the help of an absorption cooling system.

In this study, the energy potential from manure that occurs due to chicken farming in Türkiye and the Bursa region was calculated. Additionally, the poultry population in Yenişehir district was also investigated.

II. MATERIALS AND METHODS

The number of poultry was taken from the Biomass Energy Potential Atlas database, and the corresponding waste production amount based on each species was calculated using the BEPA of Türkiye. The analysis result based on the laying hen query is given in Figure 1 below.

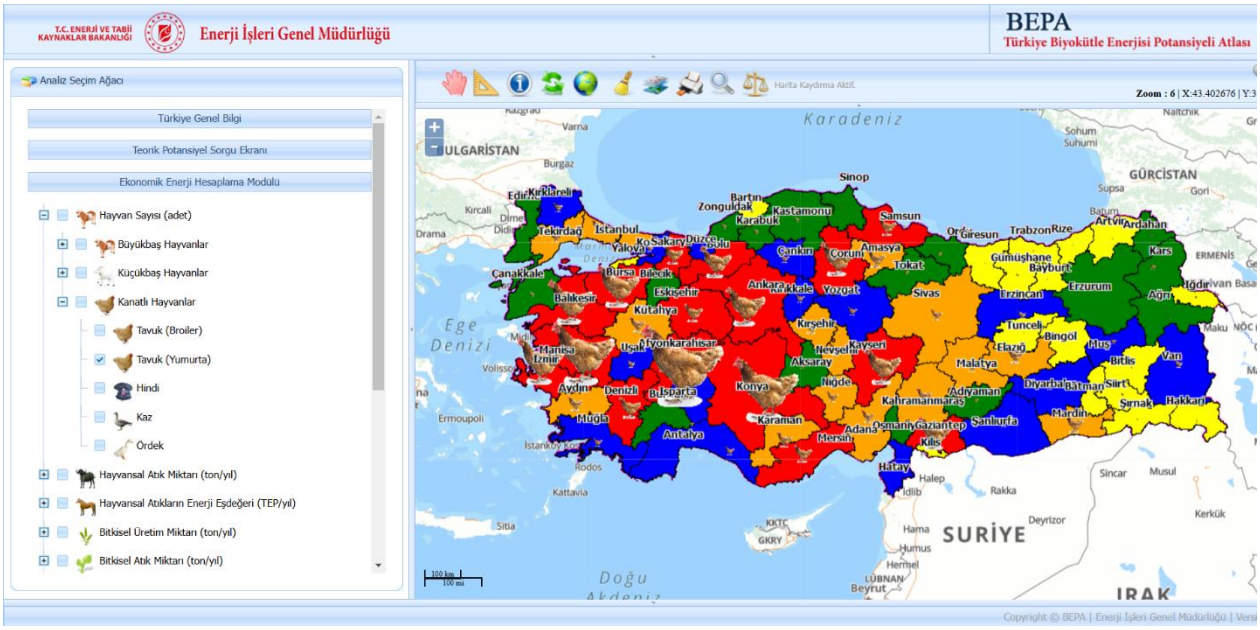

Figure 1. The interface of online BEPA with the laying hen query

The energy exploitation from animal biomass was considered to be methane combustion produced as a result of anaerobic digestion. Also, direct combustion is another useful energy obtain method. It is possible to perform analysis for sixteen different animal species using BEPA. The analysis result based on the broiler chicken query is given in Figure 2 below. As seen in the figure, data is not given for many provinces. While laying hen breeding is done in every province throughout the country, it is noteworthy that broiler breeding is not available throughout the country. According to Figure 2, there is no broiler chicken breeding in 30 different provinces across the country.

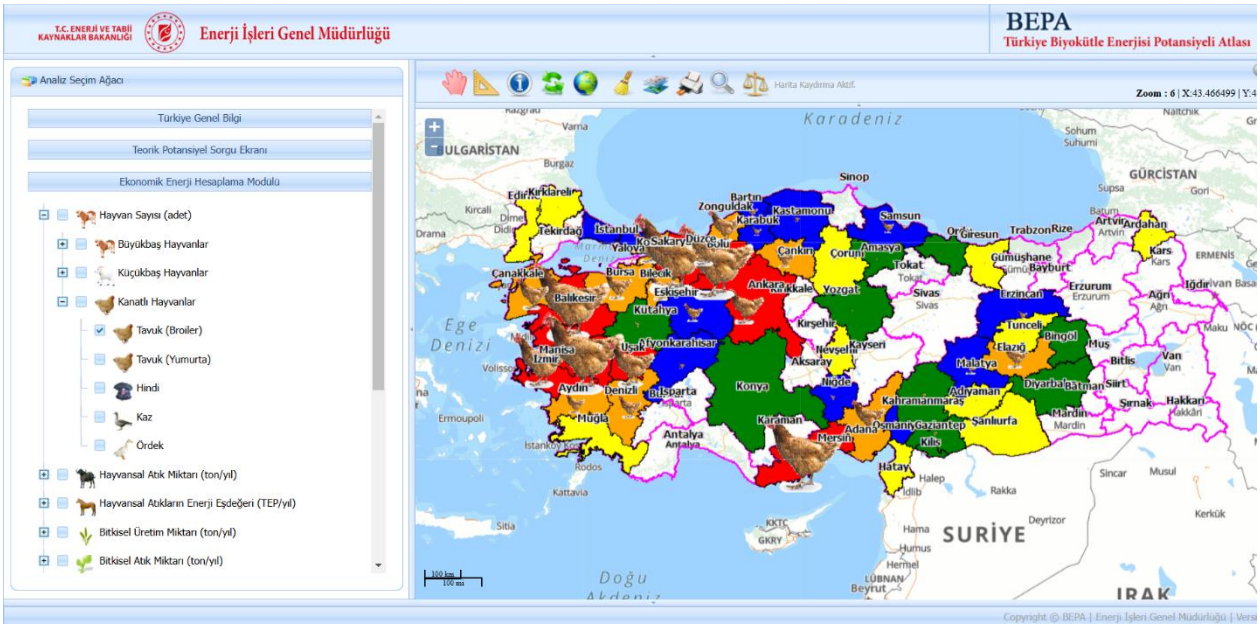

Figure 2. The interface of online BEPA with the broiler query

III. RESULTS AND DISCUSSION

Türkiye is a country with a large population in terms of animal husbandry. Animal husbandry in the country can be examined in three parts as cattle, sheep and poultry. The most important share among poultry husbandry is egg-laying hen and meat-making chicken husbandry. Table 1 below shows the comparison of poultry numbers in Türkiye with energy analysis according to direct burning values. The table defines the numbers of geese, ducks and turkeys together as others. As can be seen in the table, the number of all species of animals has continued to increase over the years.

Table 1. Comparison of poultry numbers in Türkiye with energy analysis

	Number of Animal In 2016 [4]	**Number of Animal Present Study**	**Waste (Tons)**	**Energy Equivalent (TOE/year)**
Laying hen	108,689,236	124,054,810	6,792,000.8	412,688.3
Broiler	220,322,081	229,506,689	6,196,680.6	376,516.1
Others	4,529,945	5,656,363	227,114.90	13,799.70
Total poultry	333,541,262	359,217,862	13,215,796.30	803,004.10

All provinces in the country contribute to Türkiye's poultry population. Türkiye is politically governed by 81 provinces and Bursa is only one of them. Table 2 below shows the comparison of poultry numbers in Bursa with energy analysis according to direct burning values. The most striking increase in the table is in the number of laying hens. There has been a 60% increase in this species in the last 6 years.

Table 2. Comparison of poultry numbers in Bursa with energy analysis

	Number of Animal In 2018 [20]	Number of Animal Present Study	Waste (Tons)	Energy Equivalent (TOE/year)
Laying hen	3,930,893	6,269,538	343,257.2	20,856.6
Broiler	4,997,747	4,694,577	126,753.6	7,701.7
Others	59,882	70,822	2,799.40	170.1
Total poultry	8,988,522	11,034,937	472,810.20	28,728.40

In order to make the potential biomass energy from chicken manure usable, two important methods with different assumptions come to the fore. In one of these, the biogas conversion process, the energy potential of poultry is accepted as 0.0281 toe/tons in BEPA data [4]. However, in the direct burning process, it is accepted as 0.250 toe/tons, and it is reported that only one fourth of this is economically equivalent.

Tablo 3. Number of poultry according to districts in Bursa

Districts	Broiler	Turkey	Goose	Duck	Laying hen	Total	%
Büyükorhan	0	35	82	39	7,580	7736	0.070
Gemlik	0	0	0	0	74,538	74538	0.675
Gürsu	0	34	0	0	214	248	0.002
Harmancık	0	80	20	15	1,050	1165	0.011
İnegöl	484,690	3,414	1,641	815	158,000	648560	5.877
İznik	298,000	100	100	110	18,000	316310	2.866
Karacabey	1,289,451	16,117	573	817	3,634,936	4941894	44.784
Keles	0	70	35	90	17,805	18000	0.163
Kestel	42,000	113	19	23	8,750	50905	0.461
M. Kemalpaşa	1,171,634	33,657	2,111	5,363	545,590	1758355	15.934
Mudanya	0	500	170	300	1,170,000	1170970	10.611
Nilüfer	92,790	450	280	172	13,105	106797	0.968
Orhaneli	0	265	290	265	37,500	38320	0.347
Orhangazi	77,500	184	175	232	68,720	146811	1.330
Osmangazi	0	85	431	575	97,650	98741	0.895
Yenişehir	1,238,512	235	228	270	412,400	1651645	14.967
Yıldırım	0	47	115	80	3,700	3942	0.036

Table 3 shows the distribution of poultry population in Bursa by district. There are seventeen districts in Bursa region. The four districts host more than 85% of the total population. Accordingly, 44.8% of the total number of poultry is raised in Karacabey district. Yenişehir's contribution to this population is 15%. Mustafa Kemalpaşa has 15.9% and Mudanya has 10.6%

IV. CONCLUSIONS

In this paper, energy potential of chicken manure in Türkiye was studied. Especially, energy potential of Bursa province and Yenişehir districts were focused. The following results were concluded;

- While laying hen breeding is done in every province throughout the country, it is noteworthy that broiler breeding is not available throughout the country. There is no broiler chicken breeding in 30 different provinces across the country.
- The number of all species of poultry has continued to increase over the eight years.
- The number of laying hens in Bursa increased by 60 percent.
- 44.8% of the total number of poultry animals are raised in the Karacabey district of Bursa province.
- Yenişehir's contribution to the poultry population of Bursa province is 15%.

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