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ENERGY POTENTIAL OF ANIMAL BIOMASS IN TURKEY

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In this study, animal biomass energy potential of Turkey was presented in detail based on the countrywide livestock. Animal biomass resources were examined under three major groups: bovine, small ruminant, and poultry. Bovine animals were described in terms of three different cattle species, buffalo and other species (horse, donkey, camel, mule and pig). Sheep and goat were considered as two subspecies of small ruminant. Poultry consisted of two different chicken species, turkey, goose and duck. The status of animal biomass in Turkey and its exploitation by use of anaerobic digestion and consequent combustion of methane produced for energy production were presented. A detailed analysis was made to determine which animal species has high energy potential of biomass. The potential of energy, waste and the production depending on every single subspecies were indicated in the analyses. The waste coefficients for species were obtained from the biomass energy potential atlas of Turkey and the animal production data reported by the Turkish Statistical Institute. Additionally, energy potential changes in recent years for every single species were calculated. According to the results, bovine animals possess 67.1% of total energy potential, and among bovine animals, cattle has the highest energy potential with 61%. Results indicated that 1.36 million tons of oil equivalent would be exploited by the animal biomass potential of Turkey according to the 2016 data.

Key words: Animal Biomass, Energy Potential, Waste, Species, Turkey

1. Introduction

As a renewable energy source, biomass comes out in different forms (animal, vegetable, municipal solid and forestry) based on biological diversity. This biomass diversity has drawn various communities' attention towards the utilization of bioenergy including biodiesel, bioethanol, biogas, bio

methanol and bio oil especially in developed countries as stressed by Demirbas [1]. A considerable part of the research studies made involves the evaluation of nationwide biomass potential.

India has surplus agricultural and forest area which comprises about 500 million metric tons of biomass availability per year. Renewable energy is contributed 10.5% of total generation out of which 12.83% power is being generated using biomass. In India total biomass power generation capacity is 17,500 MW. At present power being generated is 2665 MW which include 1666 MW by cogeneration [2].

The estimated total amount of biomass resource available for energy in Bangladesh in 2012–2013 is 90.21 million tons with the annual energy potential of 45.91 million tons of coal equivalent. The recoverable amount of biomass (90.21milliontons) in2012–2013 has an energy potential of 1344.99 PJ which is equivalent to 373.71 TWh of electricity [3].

Alberta's wealth of biomass resources is estimated at 458 PJ potential. Agriculture is a major source for biomass feedstock supply in Alberta. Also, biomass-based energy development has been slow, and its contribution for provincial energy supply has so far been low. Utilization of agricultural and forest biomass resources for energy production can avoid 11-15% of GHG emissions and also substitute 14-17% of final energy demand by 2030. In addition, biomass has the potential to substitute 29% of total electricity consumption or 28% of Alberta total internal load [4].

The most promising biomass feed stocks in Central America are residue based; animal (manure), forest and agricultural origin. Around 250 PJ/year could be available for the energy sector, which is equivalent to 34% of primary energy supply for Central America. It is concluded that in the short term promoting and implementing improved cooking stoves will give the largest improvement in the efficiency of biomass use, whereas on the long term small combustion plants seem to be the best choice for transforming Central America's biomass in to a clean and sustainable energy carriers, boosting economy and industrial development. The introduction of improved cooking stoves will result in an annual saving in the range of 4–8 Mt of fuel wood (59–113PJ). Moreover, even when the investment cost of the cooking stoves is considered, improved cooking stoves yield economic savings to fuel wood consumers compared to traditional stoves [5].

The total final energy which could be generated from 22,208,455 t/y of residual biomass assessed in Italy, is equal to 4.57 Mtoe, nearly 2.7% of the gross Italian energy consumption in 2013 and the total savings of GHG emissions coming from this bioenergy generation, are close to 52 Mt CO_2 for the entire Italian territory per year [6].

Rapeseed can be considered for biodiesel production in Croatia because it provides a positive energy return compared with the energy used to produce it. Considering rapeseed oil for biodiesel and meal for animal feed, the energy ratio of the rapeseed production was 3.16, the net energy gain was 50.56 GJ/ha, and the energy productivity was 49.23 L/GJ. The major energy inputs were fertilizers, with 64.9%, and fuel consumption, with 22.8% of the total energy input. On the other hand, labor was an insignificant energy input, with less than 0.1% of the total. Because the reduction of fertilizers would decrease production yields, the reduction of energy input might first be possible with regard to fuel consumption for field operations, especially in soil tillage and transport. The production of rapeseed oil for biodiesel can be a good alternative for Croatian farmers and can have economic, environmental and energy benefits for Croatia [7].

There have been a number of research studies on the determination of biomass potential in Turkey. Sürmen [8] emphasized the significance of biomass for Turkish economy and estimated the

firewood share on the overall energy production to be 21%. Sustainability of biomass was discussed and biomass gasification processes were recommended for Turkey's power generation [9-10].

Yelmen and Cakir [11] emphasized that Turkey has remarkable potential of biomass while it has poor fossil fuel resources. According to the 2004 data, animal waste derived biogas energy potential of Turkey was estimated to be 3 billion m^3 per annum [12]. This potential was predicted to be 2.18 billion m^3 per annum according to the 2009 data in case of evaluating 121 million tons of animal waste [13]. Balat et al. [14] revealed that the total biomass energy potential of Turkey was about 32 Mtoe of which 17 Mtoe could be evaluated as usable biomass. Erdogdu [15] reported the annual waste amount of animal biomass in terms of animal species. Yılmaz et al. [16] investigated the energy recovery from municipal solid waste in Turkey as landfill gas collection between 2012−2023. The results indicated that about 1% of the energy deficit of the country would be met if all the municipal solid waste potential were put into practice by sanitary landfilling till 2023.

The aim of this study is to determine the animal biomass potential of Turkey in terms of 16 animal species which were classified under three main groups as bovine, small ruminant and poultry. The number of animal for each species was taken 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 Turkey. The energy exploitation from animal biomass was considered to be methane combustion produced as a result of anaerobic digestion. Additionally, the variation of energy potential between 2010−2016 was demonstrated.

2. Biomass Energy Potential Atlas of Turkey

BEPA of Turkey [17, 18] has been prepared by General Directorate of Renewable Energy (YEGM). In this study, the waste coefficients for each animal species and the energy potentials obtained from BEPA were used as material data. In BEPA, biomass waste resources were classified into four different groups as animal, vegetable, municipal solid and forestry. For every single town within the border of the Republic of Turkey, the total amount of biomass production, the total amount of waste production and the total amount of energy potential based on the waste type are presented in detail. The biomass energy potential of each city of the country is defined to be the cumulative result of those towns locating under the corresponding city. BEPA has a user- friendly and provides online data since 2014 as schematically shown in Fig. 1 but it should be noted that the country population data is compatible with the data two year ago, i.e. 2012 due to the time lag resulting from the colossal biomass data processing. This study takes into consideration the most recent data of animal reproduction reported by TurkStat [19].

3. Waste and Energy Value

There are three main parameters for the calculation of energy potential: the animal production rate, the amount of waste per animal, the amount of energy per unit waste. The energy potential is calculated by multiplying these three parameters. The annual produced waste depends on many factors such as feeding habits, animal physiology, and weather conditions however the waste production for each animal species was taken to be averaged values for simplifying the analyses. Otherwise, collecting real data is not easy in countrywide scale. Energy exploitation from animal manure was considered to be performed by anaerobic digestion which provides to produce methane. The detail of the calculations

is given in our previous study [20] to produce energy from methane. The waste production coefficients and equivalent heating values (as tons of oil equivalent (toe)) used in this study are given in Table 1.

Figure 1. Distribution of culture cattle for cities in Turkey using BEPA interface

Table 1. The Waste Production per Animal and Energy Values per Unit Waste

Species	Waste (kg/year)	Energy (toe/tons)	Species	Waste (kg/year)	Energy (toe/tons)
Domestic cattle	5475	0.0062	Donkey	2737	0.0037
Crossbred cattle	6570	0.0075	Sheep	1095	0.0028
Culture cattle	9125	0.0093	Goat	730	0.0019
Buffalo	7300	0.0087	Hen (Broiler)	27	0.0281
Horse	5475	0.0062	Laying hen	55	0.0281
Mule	4380	0.0049	Turkey	38	0.0281
Pig	730	0.0093	Goose	47	0.0281
Camel	10220	0.0093	Duck	47	0.0281

The annual waste production by crossbred cattle and culture cattle constitutes 81.9% of the countrywide animal waste production. The waste production for bovine was reported to be 20 kg per day by Avcıoğlu and Türker [13]. This corresponds to 7300 kg/annum which agree well with the buffalo data given in Table 1.

4. Results and discussion

It is significant to discuss the contribution of the animal species to the total animal biomass production. There is a direct relationship between animal population and waste production which increases with increasing animal weight. Thus, biomass energy potential is rather related to the amount of waste than the number of animals. The animal species becomes a significant parameter as the animal population increases.

Table 2 shows the details of animal biomass and its energy potential according to the 2016 data. The calculations indicated that the waste production by bovine, small ruminant and poultry is 67.2%,

25.4% and 7.4%, respectively. The energy profit from the associated waste production is 67.1%, 8% and 24.9%, respectively. It is clearly seen that although the waste production by small ruminant is higher than that of poultry, its equivalent energy potential is lower than the poultry. 16 livestock were considered to analyze but few of them made considerable effect on the biomass energy potential. Cattle species have the highest contribution to the overall energy exploitation from the animal biomass.

Table 2. The production and waste and energy potential based on animal species in Turkey.

	Production Ratio (%)		Animal count	Waste Percent (%)		Waste (tons/year)	Energy Percent (%)		Energy (toe/year)
Domestic Cattle	11.9		1733292	8.6		9489773	6.4		58836
Culture Cattle	45.3		6588527	54.8		60120308	61		559118
Crossbred Cattle	39.6		5758336	34.5		37832267	30.9		283742
Buffalo and oth.	3.1		454679	2.1		2293573	1.7		15612
Total Bovine	100	**3.7**	14534834	100	**67.2**	109735923	100	**67.1**	917310
Sheep	75		30983933	81.8		33927406	86.9		94996
Goat	25		10345299	18.2		7552068	13.1		14348
Total Sheep	100	**10.6**	41329232	100	**25.4**	41479474	100	**8.0**	109345
Laying Hen	32.6		108689236	49.4		5977908	49.4		167979
Broiler	66.1		220322081	49.1		5948696	49.1		167158
Turkey and oth.	1.4		4529945	1.5		184262	1.5		5177
Total Poultry	100	**85.7**	333541262	100	**7.4**	12110866	100	**24.9**	340315
Total		100	389405328		100	163326265		100	1366971

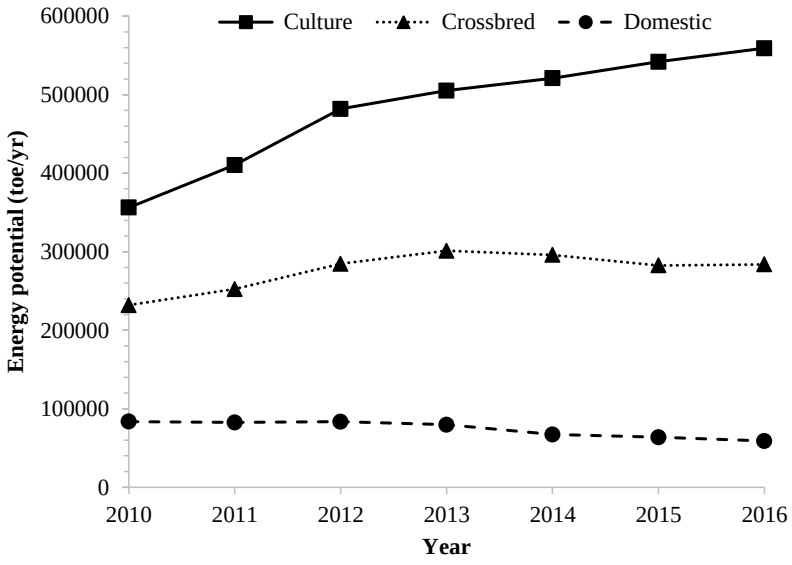

Figure 2. Energy potentials of cattle species.

The culture cattle have the share of 61% on the overall energy potential among total bovine in the countrywide. This potential is significant to be exploited especially in the southwestern part of Turkey as seen from Fig. 1. 1.36 Mtoe would be exploited by the animal biomass potential of Turkey according to the 2016 data.

Another point that was focused in this study is the change of biomass energy potential with time. This would provide to estimate the energy potential in the coming years. As seen from Fig. 2, while the energy potential of culture cattle has an increasing trend, the energy change in the crossbred cattle is almost constant in recent years. On the other hand, the trend for the domestic cattle has decreased recently. It is clearly seen that the energy potential of culture cattle is 6 times and 2 times higher than that of the crossbred and domestic type, respectively. The trend for the buffalo and other bovine animals was not given in the figure due to their low energy content.

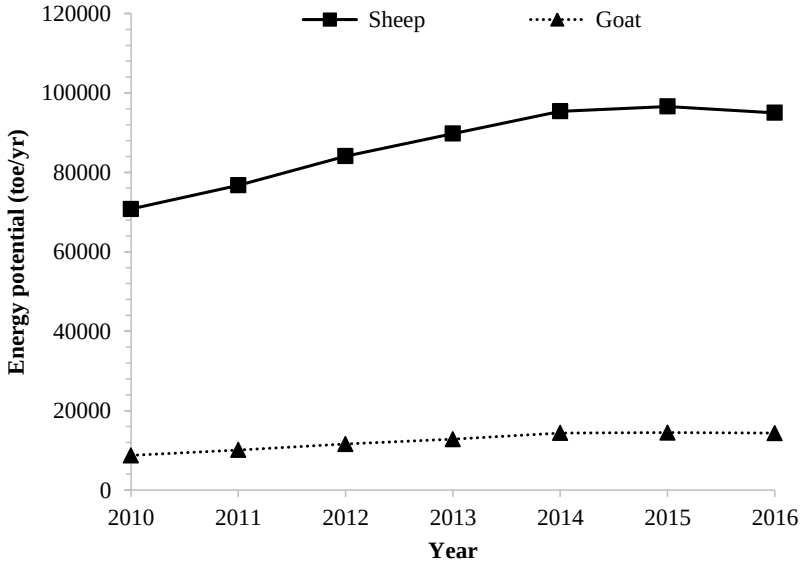

Figure 3. Energy potentials of small ruminants.

Fig. 3 shows that the rate of energy potential for small ruminants has stabilized in recent years. The contribution of sheep on the energy potential is 6.5 times higher than the goat even though the production ratio of sheep is 3 times higher than the goat. It should be noted that sheep production is statistically analyzed as domestic and merino according to the TurkStat data, and the goat species is classified into two groups as ordinary and Angora. While the sheep count for domestic and merino is 93.1% and 6.9%, respectively according to 2016, the goat count for ordinary and Angora is 98% and 2%, respectively. For this reason, the waste production by individual species was considered to be equal each other.

Fig. 4 shows the energy potentials in terms of poultry by years. The curves of broiler hen and laying hen have similar trends and increase almost linearly in recent years. The reason why the energy trends of these species are close to each other is related to the equivalent population to waste ratio. The energy potential of other poultry including turkey, duck and goose is relatively low with respect to the former ones.

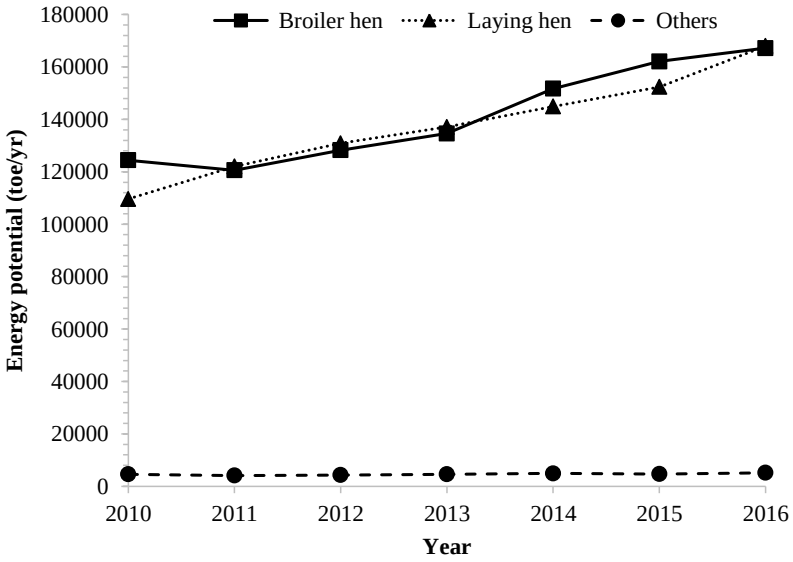

Figure 4. Energy potentials of poultry.

5. Conclusions

This study presents the status of animal biomass in Turkey and its exploitation by use of anaerobic digestion and consequent combustion of methane produced for energy production. Animal biomass resources were examined under three major topics: bovine, small ruminant, and poultry. Bovine animals were described in terms of three different cattle species, buffalo and other species (horse, donkey, camel, mule and pig). Sheep and goat were considered as two subspecies of small ruminant. Poultry consisted of two different chicken species, turkey, goose and duck. Results indicated that 1.36 Mtoe (million tons of oil equivalent) would be exploited by the animal biomass potential of Turkey according to the 2016 data. 67.1%, 8.0% and 24.9% of this potential would be obtained respectively from the biomass of bovine, small ruminant and poultry. Cattle species have the highest contribution to the overall energy exploitation from the animal biomass. The culture cattle have the share of 41% on the overall energy potential among livestock (16 species available) in the countrywide. The waste energy potential of small ruminants has leveled off while the energy exploitation from the bovine and poultry has been increasing in recent years.

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