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Comparative Theoretical Analysis of Biomass and Energy Potentials of Usable Maize and Wheat Stalk Wastes: Example of Sakarya Province

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A B S T R A C T

With the increase in the population in the world and in our country, the energy requirement related to consumer demands is constantly increasing. In our country, although wind, sun, etc. energy sources are used in energy production, fuels of fossil origin (coal, natural gas, oil etc.) are used more in energy production. Renewable energy sources, which are alternative due to the decrease in fossil fuel reserves, negative environmental effects and inability to meet the energy needs in the future, come to the fore. In this study, Turkey Statistical Institute (TUIK) according to the 2015-2019 year data, Sakarya at the central and districts in cultivation areas for cultivated of using the amounts of maize and wheat product (da) average waste, dry matter, and volatile dry matter, methane and energy their potential has been determined. As a result of the calculations, it has been determined that the maize sap waste amount has the highest 25695.68 tons of waste and 201197.15 MJ energy potential in Adapazarı district in 2017. Among the wheat stalk wastes, in 2017, Geyve district had the highest 269.95 tons of waste and 2113.72 MJ energy respectively.

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Introduction

Amounts of use are constantly decreasing, as the reserves of fossil energy sources decrease and cause irreversible environmental problems (Afazeli et al., 2014; Zareei, 2018; Tasova and Naneli, 2019). Using non-renewable resources in energy production increases greenhouse gas emission rates, but also increases global warming and climate change (Momayez et al., 2018). For this reason, the use and technologies of more environmentally friendly renewable energy sources are developing rapidly. One of the renewable energy sources is biogas. Biogas, especially used in rural areas and agro-industrial areas, is also known as green energy. It is a gas group that occurs as a result of microbial decay of organic substances in the oxygen-free environment. The biogas produced varies depending on the parameters and intensities examined in the facilities.

It contains an average of 35-75% CH_4, 25-65% CO_2, 1-5% H_2 and little amounts of ammonia, water vapor and hydrogen sulfide (Yentekakis and Goula, 2017; Ullah Khan et al., 2017; Momayez et al., 2018). Wastes, which are the raw materials of biogas; besides water, soil, and air pollution, affects human health negatively. In this context, it is necessary to manage the waste. One of these management forms is energy production within the scope of sustainable development. Energy production within the scope of sustainable development is the process of converting the fermentable biomass involved in the process of anaerobic decomposition into biogas, where methane and carbon dioxide are dense. The gas obtained as a result of the specified process is converted into electrical energy by burning it in engines as well as indirect heating processes. Also, it is processed in cogeneration units and its use as biomethane instead of natural gas increases both quality and functionality (Da Costa Gomez, 2013; San Minguela and Godoy, 2015; Ruiz et al., 2018). Organic origin waste is performed both with sustainable use of energy form conversion is inhibited greatly damages the environment (Figure 1).

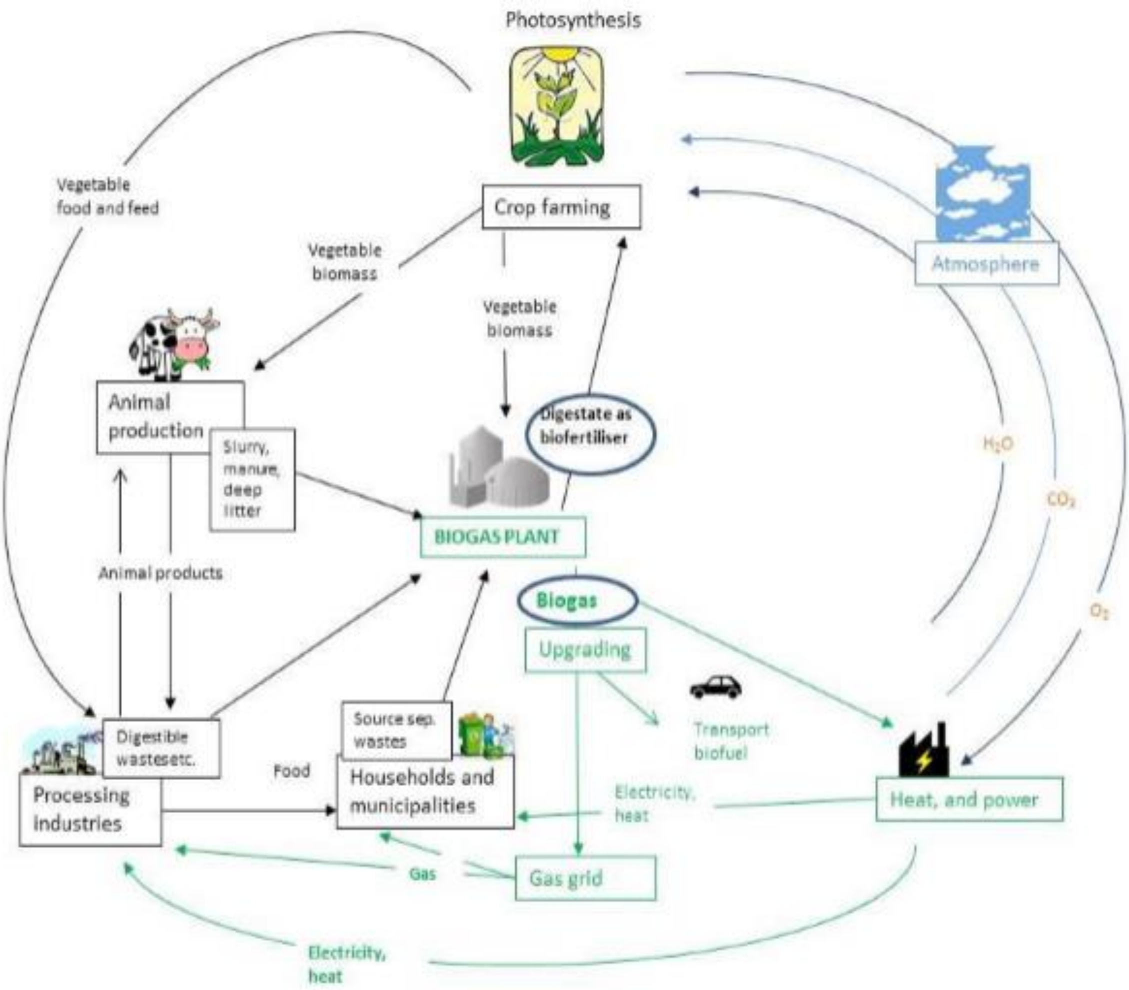

Figure 1. Conversion and use of organic wastes into energy

Biomass formed by photosynthesis is consumed by animals (Figure 1). The remaining herbal wastes, after the digestion in the biogas plant, are transformed into secondary energy as heat and electrical energy by passing through the different systems. Bionic fertilizer, which remains after the use of animal waste in biogas production, is also given to plants as a nutrient. This system continues as a closed-loop. As with all renewable energy sources, investment costs are high in the establishment of biogas facilities. For this reason, it may not be appropriate to establish the facility in any location with biological waste. Feasibility studies are carried out before the establishment of biogas facilities. At the beginning of these studies, there is an obligation to determine a waste and energy potential in the place where the facility is planned to be established. In this context, studies are carried out in the literature on determining the potential state. Khalil et al. (2019), They determined the biogas potential that can be obtained from the wastes of animal origin from Indonesia. Hazer and Ammenberg (2019), They determined the biomass, biogas, and energy potential values that can be obtained from some agricultural waste in the city of Hazaribagh, Bangladesh. Howell et al. (2019), They researched the biogas potential that can be obtained from the domestic waste coming to the municipal waste facility with the prediction method. Ramos-Suarez et al. (2019), They determined the biogas and energy potentials that can be obtained from animal waste in the Canary Islands. Besides, they stated that in this study, 495.622 tons of waste is produced annually. In this study, Turkey/Sakarya province center and districts have grown in the years 2015-2019 that the usable stalk waste amounts (ton/year), dry matter (ton/year), volatile dry matter (m^3/year) and methane gas energy potentials (MJ/year) in maize and wheat lands were investigated.

Material and Method

The Research Material

Sakarya Province of maize and wheat stalk biomass and waste to determine the energy potential of Turkey Statistical Institute (TSI)' s cultivation amounts (da) between the years 2015 to 2019 taken from the official site was used.

Calculation Methods

Between 2015-2019, sowing amounts (da) in maize and wheat fields grown based on Sakarya center and districts are given in Table 1. Average waste amounts were determined by using maize and wheat cultivation values given in Table 1 by years. While determining these values, the harvested proportions of products were used. Maize is calculated with 60% and wheat with 15% (Öztürk and Başçetinçelik, 2006). Dry matter, volatile dry matter and total methane potential values that can be obtained from wastes according to Sharma et al. (1988) the methods used. Literature data were used to determine the volatile dry matter value. Methane gas (m^3/year) and energy (MJ/year) potentials of maize and wheat wastes that can be obtained were determined according to the methods used in Aybek et al. (2015)' s studies.

The parameters and formulas used for maize are given as an example in equations 1-5.

$$AP = ((EA \times 527 \times 0.6)/1000) \quad (1)$$

Here; AP, waste potential of maize product (ton / year); EA, wheat planting area (da).

$$KM = ((AP \times 88)/100) \quad (2)$$

Here; KM, Available dry matter potential (tons/year).

$$UKM = ((AP \times 87)/100) \quad (3)$$

Here; UKM, Dry matter potential (tons/year).

$$ÖMO = (UKM \times 0.25) \quad (4)$$

Here; ÖMO, Specific methane ratio (CH_4 kg).

$$ME= (ÖMO \times 36) \quad (5)$$

Here; ME, the Energy value of available methane gas (MJ).

In the studies reviewed, the coefficients of the stalk waste that can be used for wheat and other products were specified in detail (Sharma et al., 1988; Öztürk and Başçetinçelik, 2006; Aybek et al., 2015).

Results and Discussion

The Waste Amount, Dry Matter, Volatile Dry Matter

The potential of waste, dry matter and volatile dry matter calculated from the maize field grown in the centers and districts of Sakarya province and the areas are given in Table 1.

According to Table 1, the highest collectible waste material potential for maize products in Sakarya center and districts between 2015 and 2019 was determined as 25695.68 tons/year in 2017 in Adapazarı district. According to the table, there is no data for Pamukova district. This situation is thought to be because no data record of maize cultivation was created between 2015 and 2019, or that the amount grown between the specified years was very low.

The lowest maize waste potential among the years specified outside of Pamukova district was determined in Sapanca district with 3.16 tons/year. It was observed that the same data was calculated in terms of the parameters specified in 2015, 2018 and 2019. In terms of dry matter and volatile dry matter parameter, it is the highest and the lowest potential Adapazarı and Pamukova respectively, the maximum values in 2017 in Adapazarı location were obtained. In Pamukova location, the minimum potential value was determined in all the years examined (Table 1). The findings of methane gas and energy potential that can be obtained from maize waste were given in Table 2.

According to Table 2, the methane gas and energy potentials that can be obtained from the available maize stalk wastes of Sakarya province between 2015-2019 have been determined. In line with the findings, the district with the highest methane gas and energy potential was Adapazarı in 2017. The determined values were 5588.81 m^3/year and 201197.15 MJ/year, respectively.

Available waste potentials for wheat products grown in the specified years for Sakarya centers and districts are given in Table 3.

According to Table 3, the highest potential in terms of usable waste material of wheat grown in Sakarya center and districts between 2015 and 2019 was determined in Geyve district as 269.95 tons/year in 2017. There is no data for Kocaali and Sapanca districts (Table 3). This situation is thought to be caused by the fact that there is no data record on how much wheat is cultivated between 2015 and 2019, or because the amount of cultivated area between the specified years is very low. There is no clear information about the data status of Kocaali and Sapanca districts. The lowest wheat waste potential among the specified years was determined as 0.22 tons/year in Arifiye district especially in 2019. The highest and lowest potentials in terms of dry matter and volatile dry matter parameters were found to be valid for the same location and years.

Between the years studied, the findings of methane gas and energy potentials that can be obtained from wheat wastes are given in Table 4.

According to Table 4, the methane gas and energy potentials that can be obtained from the collectible wheat stalk waste belonging to Sakarya between the years of 2015-2019 have been determined. In line with the findings, it was determined in 2017 that Geyve is the district with the highest methane gas and energy potentials. The determined values were 58.71m^3/year and 2113.72 MJ/year, respectively.

Khalil et al. (2019), They identified the biogas potential of Indonesia that can be obtained from animal wastes. They stated that 9597.4mm^3 biogas per year from animal wastes and 1.7×106 kWh/year electrical energy can be produced from the obtained gas. Bao et al. (2019), They determined the waste potential that can be obtained from farm animals in 2013-2015 in some locations in China. In the study, they determined that there is an average of 414.90 Mt dry matter potential per year from usable wet wastes. Gao et al. (2019), They determined the biogas potentials that can be obtained from the waste of olive, cotton, tuber, maize, wheat and paddy products grown in Henan city of China between 2009-2014. According to the findings, 42.24% of the biogas that can be obtained from wheat stalks, 34.50% from maize stalks, and the lowest rate can be obtained from tuberous products. In the study, it was stated that the biggest factors affecting these rates were the area in which it was grown and the yield amounts. Hasan and Ammenberg (2019), They reported that the amount of biogas that can be obtained daily from organic wastes in Hazaribagh city of Bangladesh is 6 mt. In line with the findings, biogas and energy potentials that can be obtained from organic wastes, the number of animals, the number of areas where plant products are grown, the yield of the crops in the field and the different biochemical structure of the wastes are considered as the most important factors.

Table 1. Waste and volatile dry matter potentials of maize

Locations	Year	Cultivated area (da)	Waste amount (tons/year)	Dry matter (tons/year)	Volatile dry matter (m^3/year)
Adapazarı	2015	66296	20962.80	18447.26	18237.63
	2016	72260	22848.61	20106.78	19878.29
	2017	81264	25695.68	22612.20	22355.24
	2018	75262	23797.84	20942.10	20704.12
	2019	63542	20091.98	17680.94	17480.02
Akyazı	2015	75857	23985.98	21107.67	20867.81
	2016	68367	21617.65	19023.53	18807.35
	2017	61419	19420.69	17090.21	16896.00
	2018	55930	17685.07	15562.86	15386.01
	2019	64948	20536.56	18072.17	17866.81
Arifiye	2015	11380	3598.36	3166.55	3130.57
	2016	11276	3565.47	3137.61	3101.96
	2017	10541	3333.06	2933.10	2899.77
	2018	9491	3001.05	2640.93	2610.92
	2019	10591	3348.87	2947.01	2913.52
Erenler	2015	36552	11557.74	10170.81	10055.24
	2016	34524	10916.49	9606.51	9497.35
	2017	35955	11368.97	10004.69	9891.00
	2018	32299	10212.94	8987.39	8885.26
	2019	33217	10503.22	9242.83	9137.80
Ferizli	2015	20931	6618.38	5824.18	5757.99
	2016	22517	7119.88	6265.49	6194.29
	2017	27600	8727.12	7679.87	7592.59
	2018	25291	7997.01	7037.37	6957.40
	2019	21800	6893.16	6065.98	5997.05
Geyve	2015	251	79.37	69.84	69.05
	2016	270	85.37	75.13	74.28
	2017	276	87.27	76.80	75.93
	2018	233	73.67	64.83	64.10
	2019	427	135.02	118.82	117.47
Hendek	2015	27629	8736.29	7687.94	7600.57
	2016	29723	9398.41	8270.60	8176.62
	2017	29440	9308.93	8191.86	8098.77
	2018	26977	8530.13	7506.51	7421.21
	2019	27897	8821.03	7762.51	7674.30
Karapürçek	2015	989	312.72	275.20	272.07
	2016	833	263.39	231.79	229.15
	2017	772	244.11	214.81	212.37
	2018	698	220.71	194.22	192.02
	2019	684	216.28	190.33	188.16
Karasu	2015	17298	5469.63	4813.27	4758.58
	2016	15580	4926.40	4335.23	4285.96
	2017	15640	4945.37	4351.92	4302.47
	2018	13657	4318.34	3800.14	3756.96
	2019	12054	3811.47	3354.10	3315.98
Kaynarca	2015	19908	6294.91	5539.52	5476.57
	2016	13208	4176.37	3675.21	3633.44
	2017	12492	3949.97	3475.97	3436.47
	2018	11108	3512.35	3090.87	3055.74
	2019	8336	2635.84	2319.54	2293.18
Kocaali	2015	940	297.23	261.56	258.59
	2016	808	255.49	224.83	222.28
	2017	731	231.14	203.41	201.09
	2018	637	201.42	177.25	175.23
	2019	530	167.59	147.48	145.80
Sapanca	2015	10	3.16	2.78	2.75
	2016	11	3.48	3.06	3.03
	2017	11	3.48	3.06	3.03
	2018	10	3.16	2.78	2.75
	2019	10	3.16	2.78	2.75
Serdivan	2015	6817	2155.54	1896.87	1875.32
	2016	5939	1877.91	1652.56	1633.78
	2017	11100	3509.82	3088.64	3053.54
	2018	9654	3052.59	2686.28	2655.76
	2019	8173	2584.30	2274.19	2248.34
Söğütlü	2015	53015	16763.34	14751.74	14584.11
	2016	49957	15796.40	13900.83	13742.87
	2017	56189	17766.96	15634.93	15457.26
	2018	51294	16219.16	14272.86	14110.67
	2019	49132	15535.54	13671.27	13515.92
Taraklı	2015	29	9.17	8.07	7.98
	2016	26	8.22	7.23	7.15
	2017	28	8.85	7.79	7.70
	2018	30	9.49	8.35	8.25
	2019	38	12.02	10.57	10.45
Pamukova		0	0	0	0

Table 2. Methane gas and energy potentials of maize

Locations	Year	Methane gas (m^3/year)	Energy value (MJ/year)
Adapazarı	2015	4559.41	164138.69
	2016	4969.57	178904.63
	2017	5588.81	201197.15
	2018	5176.03	186337.12
	2019	4370.01	157320.21
Akyazı	2015	5216.95	187810.25
	2016	4701.84	169266.16
	2017	4224.00	152063.99
	2018	3846.50	138474.07
	2019	4466.70	160801.25
Arifiye	2015	782.64	28175.13
	2016	775.49	27917.64
	2017	724.94	26097.89
	2018	652.73	23498.25
	2019	728.38	26221.68
Erenler	2015	2513.81	90497.12
	2016	2374.34	85476.11
	2017	2472.75	89019.04
	2018	2221.32	79967.35
	2019	2284.45	82240.18
Ferizli	2015	1439.50	51821.93
	2016	1548.57	55748.62
	2017	1898.15	68333.35
	2018	1739.35	62616.62
	2019	1499.26	53973.44
Geyve	2015	17.26	621.44
	2016	18.57	668.48
	2017	18.98	683.33
	2018	16.02	576.87
	2019	29.37	1057.19
Hendek	2015	1900.14	68405.15
	2016	2044.15	73589.57
	2017	2024.69	72888.91
	2018	1855.30	66790.90
	2019	1918.57	69068.68
Karapürçek	2015	68.02	2448.61
	2016	57.29	2062.38
	2017	53.09	1911.35
	2018	48.00	1728.14
	2019	47.04	1693.48
Karasu	2015	1189.64	42827.18
	2016	1071.49	38573.68
	2017	1075.62	38722.23
	2018	939.24	33812.63
	2019	829.00	29843.85
Kaynarca	2015	1369.14	49289.14
	2016	908.36	32700.97
	2017	859.12	30928.27
	2018	763.94	27501.70
	2019	573.30	20638.65
Kocaali	2015	64.65	2327.30
	2016	55.57	2000.48
	2017	50.27	1809.84
	2018	43.81	1577.11
	2019	36.45	1312.20
Sapanca	2015	0.69	24.76
	2016	0.76	27.23
	2017	0.76	27.23
	2018	0.69	24.76
	2019	0.69	24.76
Serdivan	2015	468.83	16877.84
	2016	408.45	14704.05
	2017	763.39	27481.89
	2018	663.94	23901.82
	2019	562.09	20235.09
Söğütlü	2015	3646.03	131256.98
	2016	3435.72	123685.84
	2017	3864.31	139115.31
	2018	3527.67	126996.04
	2019	3378.98	121643.27
Taraklı	2015	1.99	71.80
	2016	1.79	64.37
	2017	1.93	69.32
	2018	2.06	74.28
	2019	2.61	94.08
Pamukova		0	0

Table 3. Waste and volatile dry matter potentials of wheat

Locations	Year	Cultivated area (da)	Waste amount (ton/year)	Dry matter (ton/yıl)	Volatile dry matter (m^3/yıl)
Adapazarı	2015	20280	112.55	99.05	97.92
	2016	19010	105.51	92.84	91.79
	2017	18040	100.12	88.11	87.11
	2018	17719	98.34	86.54	85.56
	2019	16300	90.47	79.61	78.70
Akyazı	2015	3456	19.18	16.88	16.69
	2016	1500	8.33	7.33	7.24
	2017	1000	5.55	4.88	4.83
	2018	983	5.46	4.80	4.75
	2019	1000	5.55	4.88	4.83
Arifiye	2015	444	2.46	2.17	2.14
	2016	450	2.50	2.20	2.17
	2017	50	0.28	0.24	0.24
	2018	49	0.27	0.24	0.24
	2019	40	0.22	0.20	0.19
Erenler	2015	1677	9.31	8.19	8.10
	2016	2070	11.49	10.11	9.99
	2017	2088	11.59	10.20	10.08
	2018	1166	6.47	5.69	5.63
	2019	1000	5.55	4.88	4.83
Ferizli	2015	2962	16.44	14.47	14.30
	2016	3000	16.65	14.65	14.49
	2017	2000	11.10	9.77	9.66
	2018	1967	10.92	9.61	9.50
	2019	1800	9.99	8.79	8.69
Geyve	2015	48300	268.07	235.90	233.22
	2016	48101	266.96	234.93	232.26
	2017	48640	269.95	237.56	234.86
	2018	42199	234.20	206.10	203.76
	2019	34500	191.48	168.50	166.58
Hendek	2015	2215	12.29	10.82	10.70
	2016	1451	8.05	7.09	7.01
	2017	1234	6.85	6.03	5.96
	2018	1202	6.67	5.87	5.80
	2019	1000	5.55	4.88	4.83
Karapürçek	2015	91	0.51	0.44	0.44
	2016	69	0.38	0.34	0.33
	2017	58	0.32	0.28	0.28
	2018	51	0.28	0.25	0.25
	2019	50	0.28	0.24	0.24
Karasu	2015	1230	6.83	6.01	5.94
	2016	1217	6.75	5.94	5.88
	2017	1089	6.04	5.32	5.26
	2018	1057	5.87	5.16	5.10
	2019	1038	5.76	5.07	5.01
Kaynarca	2015	36423	202.15	177.89	175.87
	2016	24501	135.98	119.66	118.30
	2017	22435	124.51	109.57	108.33
	2018	22146	122.91	108.16	106.93
	2019	22050	122.38	107.69	106.47
Kocaali		0	0	0	0
Sapanca		0	0	0	0
Serdivan	2015	985	5.47	4.81	4.76
	2016	961	5.33	4.69	4.64
	2017	494	2.74	2.41	2.39
	2018	345	1.91	1.68	1.67
	2019	600	3.33	2.93	2.90
Söğütlü	2015	2962	16.44	14.47	14.30
	2016	3500	19.43	17.09	16.90
	2017	2000	11.10	9.77	9.66
	2018	1967	10.92	9.61	9.50
	2019	3000	16.65	14.65	14.49
Taraklı	2015	34652	192.32	169.24	167.32
	2016	20280	112.55	99.05	97.92
	2017	19010	105.51	92.84	91.79
	2018	18040	100.12	88.11	87.11
	2019	17719	98.34	86.54	85.56
Pamukova	2015	16300	90.47	79.61	78.70
	2016	3456	19.18	16.88	16.69
	2017	1500	8.33	7.33	7.24
	2018	1000	5.55	4.88	4.83
	2019	983	5.46	4.80	4.75

Table 4. Methane gas and energy potentials of wheat

Locations	Year	Methane gas (m^3/year)	Energy value (MJ/year)
Adapazarı	2015	24.48	881.30
	2016	22.95	826.11
	2017	21.78	783.96
	2018	21.39	770.01
	2019	19.68	708.34
Akyazı	2015	4.17	150.19
	2016	1.81	65.18
	2017	1.21	43.46
	2018	1.19	42.72
	2019	1.21	43.46
Arifiye	2015	0.54	19.29
	2016	0.54	19.56
	2017	0.06	2.17
	2018	0.06	2.13
	2019	0.05	1.74
Erenler	2015	2.02	72.88
	2016	2.50	89.95
	2017	2.52	90.74
	2018	1.41	50.67
	2019	1.21	43.46
Ferizli	2015	3.58	128.72
	2016	3.62	130.37
	2017	2.41	86.91
	2018	2.37	85.48
	2019	2.17	78.22
Geyve	2015	58.30	2098.95
	2016	58.06	2090.30
	2017	58.71	2113.72
	2018	50.94	1833.82
	2019	41.65	1499.25
Hendek	2015	2.67	96.26
	2016	1.75	63.06
	2017	1.49	53.63
	2018	1.45	52.23
	2019	1.21	43.46
Karapürçek	2015	0.11	3.95
	2016	0.08	3.00
	2017	0.07	2.52
	2018	0.06	2.22
	2019	0.06	2.17
Karasu	2015	1.48	53.45
	2016	1.47	52.89
	2017	1.31	47.32
	2018	1.28	45.93
	2019	1.25	45.11
Kaynarca	2015	43.97	1582.82
	2016	29.58	1064.73
	2017	27.08	974.95
	2018	26.73	962.39
	2019	26.62	958.22
Kocaali		0	0
Sapanca		0	0
Serdivan	2015	1.19	42.80
	2016	1.16	41.76
	2017	0.60	21.47
	2018	0.42	14.99
	2019	0.72	26.07
Söğütlü	2015	3.58	128.72
	2016	4.22	152.10
	2017	2.41	86.91
	2018	2.37	85.48
	2019	3.62	130.37
Taraklı	2015	41.83	1505.85
	2016	30.63	1102.84
	2017	31.34	1128.13
	2018	32.94	1185.93
	2019	22.57	812.64
Pamukova	2015	17.83	641.72
	2016	4.39	158.18
	2017	4.35	156.62
	2018	4.25	152.92
	2019	4.39	158.18

Conclusion and Recommendations

Within the scope of the study, usable maize, wheat waste and energy potentials between 2015-2019 in Sakarya city center and its districts were determined. In line with the obtained results, it was determined that the waste and energy values that can be obtained from maize waste in Sakarya province are in Adapazarı district. The highest waste and energy values in Adapazarı district were determined as 25695.68 tons/year and 201197.15 MJ/year, respectively. The highest potential for waste and energy from wheat wastes was found in Geyve district as 269.95 tons/year and 2113.72 MJ/year, respectively. As in the global dimension, transferring the energy potentials that can be obtained from the existing agricultural wastes in our country will contribute to the reduction of our energy dependency.

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