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FUEL CONSUMPTION AND CO_2 EMISSIONS IN SILAGE CORN PRODUCTION IN KOCAELI PROVINCE OF TURKEY

Hakan GOKER[1], Hasan Huseyin OZTURK[1], Hasan Kaan KUCUKERDEM[2]

[1]University of Cukurova, Faculty of Agriculture, Department of Machinery and Technologies Engineering, 01330, Balcalı, Sarıcam, Adana, Turkey
[2]Igdir University, Faculty of Agriculture, Department of Biosystem Engineering, Igdir, Turkey

Corresponding author email: hhozturk@cu.edu.tr

Abstract

In this study, total fuel (diesel +motor oil) consumption, energy consumption and carbon dioxide (CO_2) emission in silage maize production in Kocaeli region were evaluated. 195.145 L/ha fuel (Diesel + lubrication r oil) is consumed in usage of tools and machinery in silage maize production. For this process, a total of 7241.62 MJ/ha of diesel and motor oil consumption is made. In silage maize production, 535.92 kg CO_2 emission is produced regarding the consumption of 193.28 /ha diesel and 1,864 L/ha motor oil. In this region, 4.8447 L total fuel (Diesel + lubrication oil) and 179.782 MJ energy were consumed to produce 1 ton of silage maize. In result of total fuel consumption, 13.3049 kg CO_2 is released for 1 ton of silage maize production.

Key words: *Kocaeli, Silage maize, Fuel consumption, Energy consumption, CO_2 emission.*

INTRODUCTION

Carbon dioxide (CO_2) comes first among the greenhouse gases and this effect is global. Some pollutants have local characteristics such as acid rains caused by SO2 emission. Greenhouse gases are released through both natural processes and human activities. The most important natural greenhouse gas in the atmosphere is water vapor. However, human activities increase the atmospheric concentrations of these gases, causing large amounts of greenhouse gases to be released. This situation warms the climate by increasing the greenhouse effect.

According to the data of Turkish Statistical Institute (TUIK, 2019), total greenhouse gas emissions in Turkey was realized as 496.1 million tons of carbon dioxide equivalent in 2016. In this period, the largest share of CO_2 emissions in total emissions was energy-related emissions with 72.8%, followed by industrial processes and product use with 12.6%, agricultural activities with 11.4% and waste with 3.3%, respectively. Total greenhouse gas emissions in 2016 as CO_2 equivalent increased by 135.4% compared to 1990.While the carbon dioxide equivalent emission per capita was calculated as 3.8 tons/person in 1990, this value was realized as 6.3 tons/person in 2016. In 2016, 33.1% of total CO_2 emissions were from electricity and heat production, 86.1% was from energy, 13.6% was from industrial processes and product use, 0.3% was from agricultural activities and waste. 55.5% of methane emissions originated from agricultural activities, 25.8% from waste, 18.6% from energy and 0.03% from industrial processes and product use. Agricultural activities constituted the biggest share in diazo monoxide (NO_2) emissions with 77.6%. This was followed by energy with 12.1%, waste with 6.5%, and industrial processes and product use with 3.8%.

In Turkish National Energy Efficiency Action Plan for the period between years 2017-2023 (UEVEP, 2017), 6 actions have been determined like to encourage the renewal and increase energy efficiency of tractors and combined harvesters to increase energy efficiency in the agriculture sector and introduction of energy-efficient irrigation methods, promotion of energy efficiency projects in the agricultural sector to encourage the use of renewable energy sources in agricultural production, to identify and promote the use of agricultural by-products and waste potential in order to obtain biomass, and to support energy efficiency in the aquaculture industry.

One of the important silage plants is maize. Maize silage is used extensively in the feeding of animals, calves, dry and lactating cows in modern farms. Maize silage should be backed with protein, mineral and sometimes energy to meet adequate nutrition requirements of the animals in question. The feeding strategy for maize silage given to beef cattle due to its high grain content differs from other roughages. Considering the balance of beef cattle rations, maize silage's important quality factors are; energy content, cellulose content, starch content and digestion degree. The supply of energy and protein constitutes a significant part of the beef cattle ration cost. Therefore, maize silage is the most logical alternative feed raw material for providing sufficient energy in beef cattle feeding programs (Tezel, 2018). When silage is mentioned all over the world, the first plant that comes to mind is maize. Maize cultivation and seed are easy to find. Production per unit area is high also it is suitable for mechanized agriculture. Feeding value is good. It is suitable for silage and has a high rate of soluble carbon hydrates and dry material. Therefore, it is easily fermented and maintains its quality for a long time (Tan, 2015).

In this study, it was aimed to determine the total energy consumption (diesel + motor oil) in silage maize production in Kocaeli and to determine the energy efficiency of the production. For this purpose, the processes and fuel consumption in the production of silage maize in the districts of Kocaeli region were examined in detail. The diesel consumption values of the tools and machinery used in the production of silage maize were determined by surveys conducted with experts in the Agriculture and Forestry District Directorates. During the process of silage maize production, efficiency criteria for total fuel (Diesel + lubrication oil) consumption for the tractor engine in the use of equipment and machinery are defined as follows, based on production and consumption and CO_2 emission values.

MATERIALS AND METHODS

Materials

Kocaeli is Turkey's tenth most populous province and is one of Turkey's largest industrial and commercial city. It is the third largest city in Marmara Region after Istanbul and Bursa (Figure 3.1). As of 2019, it has a population of 1 906 391 people. It's name comes from Akcakoca, who conquered the region of Izmit in 1320. It is neighbor to Istanbul, Sakarya, Bilecik, Bursa and Yalova provinces. The area of the province is 3 397 km². 539 people per km² in the province. The highest population ratio is in Darica with 8 310 people per km². The annual population growth rate in the province was 2.85%.

Geographical Features

Kocaeli province is located between 29°22'-30°21' East longitude, 40°31'-41°13' North latitude in the Catalca-Kocaeli side of the Marmara Region. It is surrounded by Sakarya on the east and southeast, Bursa on the south, Yalova province, Gulf of Izmit, Marmara Sea and Istanbul on the west, and the Black Sea on the North 30° East longitude, passing by the east of the city center of Izmit and time is considered as base for Turkish local time. The surface area of Kocaeli province is 3.505 km² and it is located at an important road junction connecting Asia and Europe.

Crop Production

Population and land assets of Kocaeli districts are given in Table 1. Within the total area of 342 001 ha of the province, the cultivated area is 72 579 ha and it covers 21.2% of the province area. Within the total cultivated agricultural area, the field farming area is 56424.4 ha and the production is 450 870 tons, the fruit farming area is 12 548.1 ha and the production is 51 829 355 tons, the vegetable farming area is 3 166.5 ha and the production is 79 373 tons, the covered (green house) farming area is 314.8 ha and production is 17 512 314 tons.

Table 1. Population and Land Area of Kocaeli Districts

Dist.name	Population	Area (ha)
Basiskele	97 817	21 711.3
Derince	140 982	19 460.3
Dilovası	47 948	13 385.7
Gebze	371 000	42 514.5
Golcuk	162 584	22 629.4
Izmit	363 416	48 447.2
Kandıra	51 348	85 471.3
Karamursel	56 604	25 460.1
Kartepe	118 066	26 913.8
Korfez	165 503	30 742.5
Çayırova	129 655	2 903.2
Darıca	201 468	2 361.3
Total	**1 906 391**	**342 001.3**

In 2018, in Kocaeli, silage maize farming was made in 56 116 ha area. The total of 185 379 tons of maize has been cultivated and the output per hectare is 3 304 kg.

Methods

Calculation of Total Fuel Consumption

The diesel and engine oil values per unit production area (da) consumed by tractor during silage maize production processes were evaluated as total fuel consumption.

$TFC = DC+MYT$……………………………(1)

Where:

TFC = Total fuel consumption (L/ha)

DC = Diesel consumption (L/ha)

LOC = Lubrication oil consumption (L/ha)

Calculation of Lubricant Consumption

Lubrication oil (lubricant) consumption per hour for tractor used in silage maize production operations was determined as follows, depending on the tractor's highest PTO power (Ozturk, 2010).

$LOC = 0.00059 \times PTO_{max} + 0.02169$…….........(2)

Where:

LOC = Tractor lubrication oil consumption per hour (L/h)

PTO_{max} = Tractor's highest PTO power (kW)

The maximum tail shaft power (PTO_{max}) for the agricultural tractor used for silage maize production is taken into account as 88% of the tractor rated power (TRP, kW) and is determined as follows (Ozturk, 2010).

$PTO_{max} = 0.88 \times TRP$……………..................(3)

Where;

PTO_{max} = Tractor's highest *PTO* power (kW)

TRP = Tractor rated power (kW)

Determination of Total Energy Consumption

The total energy consumption (*TEC*, MJ/ha) pertaining to the consumption of diesel and engine oil per unit production area (da) was determined by the tractor used during silage maize production processes are as follows.

$TEC = DEC+LEC$…………………………(4)

Where

TEC = The total energy consumption (MJ/ha)

DEC = Diesel energy consumption (MJ/ha)

LEC = Lubrication oil energy consumption (MJ/ha)

Calculation of Diesel Energy Consumption

The diesel energy consumption (*DEC*, MJ / ha) related to diesel consumption consumed per unit production area (ha) by the tractor used during silage maize production processes is determined as follows.

$DEC = DC \times LHV_D$…………………………(5)

Where;

DEC = Diesel energy consumption (MJ/ha)

DC = Diesel consumption (L/ha)

LHV_D = Lower Heating Value of Diesel (MJ/L)

The lower thermal value of the diesel (fuel) consumed by the tractor during agricultural production using agricultural tools and machinery was considered as 37.1 MJ/L (IPCC, 1996).

Calculation of Lubrication Oil Energy Consumption

The lubrication oil energy consumption (*LEC*, MJ/ha) per unit production area (ha) consumed by tractor used during silage maize production processes was determined as follows.

$LEC = LOC \times LHV_L$……………….................(6)

Where;

LEC = Lubrication oil energy consumption (MJ/ha)

LOC = Lubrication oil consumption (L/ha)

LHV_L = Lower Heating Value of lubrication oil (MJ/L)

The lower heat value of the lubrication oil consumed by the tractor during the production operations in the field area with agricultural tools and machinery was taken into account as 38.2 MJ/L (IPCC, 1996).

Calculation of CO_2 Emissions

The CO_2 emissions from all motor vehicles burning fossil fuels can be calculated taking into account the amount of fuel consumed and the distance travelled. In the method of calculating CO_2 emissions taking into account the amount of fuel consumed, the value of fuel consumption is multiplied by the CO_2 emission factor for each type of fuel. This emission factor is developed depending on the thermal value of the fuel and the carbon fraction oxidized in the fuel and the carbon content. This approach is defined as the fuel-based CO_2 emission calculation method as it uses average fuel consumption data. The fuel consumption-based approach can be applied taking into account vehicle effectiveness data and fuel economy factors that enable the calculation of fuel consumption. Distance-based emission factors are taken into account when calculating emissions using the distance-based method. The fuel-based CO_2 emission calculation method is the preferred approach, since data on the fuel consumed is generally more reliable. However, since the uncertainty level in CO_2 estimates can be quite high, the distance based method should be used as a last remedy (IPCC, 1996).

Fuel Heating Values and Selection of Emission Factors

Taking into consideration the lubrication oil consumption value of the tractor engine, CO_2 emissions related to oil consumption can also be calculated. The values given in Table 2 are used for the thermal values of diesel fuel and engine oil and CO_2 emission factors depending on the type of fuel.

Table 2. Thermal Values and CO_2 Emission Factors (IPCC, 1996)

Fuel	Lower heating value (MJ/L)	CO_2 Emission factor (kg CO_2/MJ)
Diesel	37.1	0.07401
Lubricant oil	38.2	0.07328

Calculation of total CO_2 Emissions

In calculating the CO_2 emissions released in result of silage maize production, the fuel-based CO_2 emission calculation method proposed in the Intergovernmental Panel on Climate Change was taken into account (IPCC, 1996). The proposed approach to calculate CO_2 emissions based on fuel consumption is summarized in equations (8) and (9).

The total CO_2 emission (TCO_2E, kg CO_2/ha) pertaining to the consumption of diesel and engine oil per unit production area (da) was determined by the tractor used during silage maize production processes as follows.

$TCO_2E = CO_2E_D + CO_2E_L$ …………………(7)

Where;

TCO_2E = Total CO_2 emission (kg CO_2/ha)

CO_2E_D = CO_2 emission related to Diesel consumption (kgCO_2/ha)

CO_2E_L = CO_2 emission related to lubricant oil consumption (kgCO_2/ha)

Calculation of CO_2 Emission Related to Diesel Consumption

The CO_2 emission (CO_2E_D, kg CO_2/ha) for diesel consumption per unit production area (ha) was determined by the tractor used during silage maize production processes as follows:

$CO_2E_D = DC \times LHV_D \times EF_D$ ……………….(8)

Where:

CO_2E_D = The CO_2 emission related to Diesel consumption (kg CO_2/ha)

DC = Diesel consumption (L/ha)

LHV_D = Lower Heating Value of Diesel fuel

EF_D = The CO_2 emission factor for Diesel fuel (0.07401 kg CO_2/MJ)

CO_2 Emission Calculation Related to Lubrication Oil Consumption

The CO_2 emission (CO_2E_L, kg CO_2/ha) related to engine oil consumption per unit production area (ha) was determined by the tractor used during silage maize production processes as follows.

$CO_2E_L = LOC \times LHV_L \times EF_L$ …………………(9)

where:

CO_2E_L = The CO_2 emission related to lubrication oil consumption (kg CO_2/ha)

LOC = Lubrication oil consumption (L/ha)

LHV_L = Lower Heating Value of lubrication oil (38.2 MJ/L)

EF_L = The CO_2 emission factor for lubrication oil (0.07401 kg CO_2/MJ)

RESULTS AND DISCUSSIONS

Total Fuel Consumption on Silage Maize Production

During silage maize production processes, the sum of the diesel and engine oil consumption values consumed by the tractor engine in the use of tools and machinery was taken into account as the total fuel consumption. During silage maize production processes, the change in the total fuel consumption values related to the use of tools and machinery are given in Table 3.

The total fuel consumption values given in Table 3 indicate the average values of the total fuel consumption values determined from the districts of Kocaeli. It is seen that the total fuel consumption values are in parallel with the change in the usage time of the tools and machines used in the silage maize production processes and the loading rates of the tractor engine. The highest total fuel consumption occurs in silage maize harvesting operations with value of 33.422 L per unit area (ha). The second place in total fuel consumption is plough tillage applications with a value of 26.695 L/ha. The total fuel consumption in silage maize production, 23.61 L/ha in sowing process with planting machine, 21.77 L/ha in fertilizer intermediate hoeing process, 20.69 L/ha in sprout with disc harrow, 21.98 L/ha in fertilizer distribution process is 19.816 L/ha in cultivation with cultivator, 18.559 L/ha in spraying with sprayer, and 10.283 L/ha in scaling. A total of 195.145 L/ha fuel (diesel + lubrication oil) is consumed in the use of tools and machinery in silage maize production.

Table 3. The Total Fuel Consumption Values in Silage Maize Production

Equipments/ Machines	Fuel Consumption (L/ha)		
	Diesel consumption (L/ha)	Lubricant consumption (L/ha)	Total (L/ha))
Plough	26.44	0.255	26.695
Cultivator	19.63	0.186	19.816
Disc harrow	20.69	0.198	20.888
Chisel plough	10.19	0.093	10.283
Fertilizer sprayer	19.70	0.192	19.892
Planter	23.38	0.230	23.610
Fertilizer distributor with hoeing	21.77	0.210	21.980
Sprayer	18.38	0.179	18.559
Harvester	33.10	0.322	33.422
Total	**193.28**	**1.864**	**195.145**

Total Energy Consumption Related to Total Fuel Consumption

In the process of silage maize production, the sum of the energy values related to the Diesel and lubrication oil consumption consumed by the tractor engine in the use of tools machinery was taken into account as the total energy consumption related to the total fuel consumption. In the process of silage maize production processes, the change of the total energy consumption values related to the total fuel consumption related to the use of tools and machinery are given in Table 4.

Table 4. Energy Consumption Related to Fuel Consumption in Silage Maize Production

Equipments/ Machines	Energy consumption(MJ/ha)		
	Fuel consumption (MJ/ha)	Lubricant consumption (MJ/ha)	Total (MJ/ha)
Plough	981.05	9.75	990.80
Cultivator	728.26	7.11	735.37
Disc harrow	767.75	7.57	775.32
Chisel plough	377.87	3.54	381.41
Fertilizer spreader	730.96	7.35	738.31
Planter	867.34	8.78	876.12
Fertilizer distributor with hoeing	807.24	8.03	815.27
Sprayer	681.84	6.83	688.67
Harvester	1228.06	12.29	1240.35
Total	**7170.37**	**71.25**	**7241.62**

Energy consumption values related to total fuel consumption given in Table. 4 indicate the average values of energy consumption values for total fuel consumption determined from the districts of Kocaeli. It is seen that the total energy consumption values related to the total fuel consumption are in parallel with the change in the usage time of the tools and machines used in the silage maize production processes and the loading rates of the tractor engine. Total energy consumption related to the highest total fuel consumption is realized in silage maize harvesting with 1 240,35 MJ per unit area (ha).

The second place in energy consumption regarding total fuel consumption is plough tillage applications with a value of 990.8 MJ/ha. Total energy consumption for total fuel consumption in silage maize production is 876.12 MJ/ha, respectively in cultivation process 815.27 MJ/ha, in fertilizer intermediate hoeing process, 775.32 MJ/ha, in cultivation of the disc harrow, 738 MJ/ha, in the fertilizer distribution process, 31 MJ/ha, 735.37 MJ/ha in cultivation with cultivator, 688.67 MJ/ha in spraying with sprayer, and finally 381.41 MJ/ha in plough cultivation. For the use of tools and machinery in silage maize production, a total of 7 241.62 MJ/ha of Diesel and lubrication oil consumption is made.

The Total CO_2 Emission Related to Total Fuel Consumption

In silage maize production processes, the total CO_2 emission values regarding the Diesel and lubrication consumption made by the tractor engine in the use of tools and machinery were taken into account as the total CO_2 emission related to the total fuel consumption. In silage maize production processes, the change in the total CO_2 emission values related to the total fuel consumption related to the use of tools and machinery are given in Table.5.

The CO_2 emission values for total fuel consumption given in Table 5 indicate the average values of CO_2 emission values for total fuel consumption determined from the districts of Kocaeli province.

It is observed that the total CO_2 emission values related to the total fuel consumption are in parallel with the change in the usage time of the tools and machines used in the process of silage maize production and the loading rates of the tractor engine.

Table 5. The CO_2 Emission Related to Fuel Consumption in Silage Maize Production

Equipments/ Machines	CO_2 Emission (kgCO_2/ha)		
	Fuel consumption (kg CO_2/ha)	Lubrication (kg CO_2/ha)	Total (kg CO_2/ha)
Plough	72.61	0.715	73.33
Cultivator	53.90	0.521	54.42
Disc harrow	56.82	0.555	57.38
Chisel plough	27.97	0.259	28.23
Fertilizer spreader	54.10	0.539	54.64
Planter	64,19	0.645	64.84
Fertilizer distributor with hoeing	59.74	0.589	60.33
Sprayers	50.46	0.501	50.96
Harvesting	90.89	0.900	91.79
Total	**530.68**	**5.224**	**535.92**

The highest total CO_2 emission related to total fuel consumption is realized in silage maize harvesting processes with 91.79 kg CO_2 per unit area (ha). The second place in CO_2 emission related to total fuel consumption is plough tillage applications with a value of 73.33 kg CO_2/ha. Total CO_2 emission related to total fuel consumption in silage maize production, 64.84 kg CO_2/ha in sowing process, 60.33 kg CO_2/ha in fertilizer intermediate hoeing process, 57.38 kg CO_2/ha in soil cultivation with disc harrow, 54 in fertilizer distribution process, 64 kg CO_2/ha, 54.22 kg CO_2/ha in tillage, 50.96 kg CO_2/ha in spraying with sprayer and 28.23 kg CO_2/ha in tillage. In the use of tools and machinery in the production of maize silage, 535.92 kg of CO_2 emission is realized regarding the consumption of 193.28 L/ha Diesel and 1.864 L/ha lubrication oil.

CONCLUSIONS

Total consumption of fuel (diesel+lubrication oil) in silage maize production is 33.422 L/ha in harvesting process with silage machine, 26.695 L/ha in tillage with plough, 23.61 L/ha in planting machine, 21.77 L/ha in fertilizer cultivation, 20.69 L/ha in soil tillage with disc harrow, 21.98 L/ha in fertilizer distribution, 19.816 L/ha in tillage with cultivator, 18.559 L/ha in spraying with sprayer, and finally in tillage with chisel plough it is realized as10.283 L/ha.

The total energy consumption for total fuel consumption in silage maize production is 1240.35 MJ/ha in harvesting process with silage machine, 990.8 MJ/ha in tillage with plough, 876.12 MJ/ha in sowing with seed drill, intermediate hoeing with fertilizer 815.27 MJ/ha, 775.32 MJ/ha in tillage with disc harrow, 738.31 MJ/ha in fertilizer distribution, 735.37 MJ ha in tillage, 688.67 MJ/ha in spraying with sprayer and in land cultivation, it is 381.41 MJ/ha.

The total CO_2 emission related to total fuel consumption in silage maize production, 91.79 kg CO_2/ha in harvesting process with silage machine, 73.33 kg CO_2/ha in soil cultivation with plough, 64.84 kg CO_2/ha in cultivation with seed drill, 64.84 kg CO_2/ha in fertilizer cultivation 60.33 kg CO_2/ha, 57.38 kg CO_2/ha in soil cultivation with disc harrow, 54.64 kg CO_2/ha in fertilizer distribution, 54.22 kg CO_2/ha in cultivation with cultivator, 50.96 kg CO_2/ha in spraying and 28.23 kg CO_2/ha in soil cultivation with chisel plough.

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