MAIZE PRODUCTION FOR ENERGY PURPOSES - THE EMISSION LOAD

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Abstract

The trend of increase in energy consumption has been recorded in a civilized society. Fossil fuels are the main sources. However, their world's reserves are limited. Therefore, developed countries pursue the possibilities of substituting for them. The solution may be renewable energy resources. Besides water and solar energy, biomass has the greatest potential. Its combustion, but also the transformation into biogas - a mixture of methane, carbon dioxide and other minor gases - are the most common possibilities for its use. Biogas produced by fermentation of plant biomass (phytomass) in biogas stations (BGS) ranks among the promising renewable energy sources. The input material of these stations is not only the biodegradable waste, but especially the phytomass grown on agricultural land. Maize (*Zea mays* L.) has been used most often so far for this purpose due to its high yields and a favorable chemical composition. However, maize production itself and especially technical processes associated with it participate in the anthropogenic emission production that contribute to the greenhouse effect. This article presents the results of monitoring of emission load resulting from the cultivation of maize (Zea mays L.) for energy purposes. As a tool for emission load measuring, the simplified LCA method, respectively its *Climate change* impact category, was used. For the calculations, the SIMAPro software and the ReCiPe Midpoint (H) Europe method were used. The input data were determined from the field experiments conducted on the lands of the University of South Bohemia in České Budějovice and supplemented with data from the Ecoinvent database. The life cycle modelling includes the farming phase (field emissions, seeds and seedlings, fertilizers, plant protection products, agrotechnical operations) and the functional unit of the whole process was 1 kg of dry matter of maize. The results show that the total emission load in the maize cultivation (with a total yield of 19.25 $t \cdot ha^{-1}$ DM) is 0.1499 kg $CO_2e \cdot kg^{-1}$ DM and 0.04496 kg $CO_2e \cdot kg^{-1}$ GM (at a dry matter content of 32%). The highest amount of the total CO_2e burden comes from the nitrogen fertilizer application (0.06362 kg CO2e $\cdot kg_2$ DM) which is used for the fertilization of maize. 405.5 l of methane $\cdot kg^{-1}$ DM were obtained in survey tests of methane yield on average. $0.3696 \cdot 10^{-3}$ kg of CO_2e represents the emission load of one liter of methane.

Key words: maize, greenhouse gases emissions, Life Cycle Assessment, crop production

One of the main conditions for sustainable development is the efficient use of non-renewable energy sources and the gradual transition to renewable sources (RES) whose importance has been growing (Twidell, Weir, 2015). Besides water and solar energy, biomass has a great potential (Mastný et al., 2011; Havlíčková et al., 2007; Lund, 2007; Omer, 2008). Biomass is (owing to natural conditions) one of the most important renewable energy sources in the Czech Republic (Libra and Poulek, 2007). Its combustion, but also the transformation into biogas are the most common possibilities for its use in the Czech Republic (Pastorek, Kára, Jevič, 2004; Dvořáček, 2011). Biogas produced by fermentation of plant biomass (phytomass) in biogas stations (BGS) ranks among the promising renewable energy sources (Deublein, Steinhauser, 2011). The input material of these stations is not only the biodegradable waste, but especially the phytomass grown on agricultural land (Jaroslav et al., 2007). Maize (*Zea mays L.*) has been used most often so far for this purpose due to its high yields and a favorable chemical composition (Weger et al., 2012) and a significant amount of maize is grown specifically for the purpose of BGS in the Czech Republic (Sikora, 2015).

Besides the well known erosion risks (Petříková, 2013), maize production brings also other environmental problems. These include, for example, the production of anthropogenic emissions that contribute to the greenhouse effect. Indeed, as the entire agriculture (Cole, 1997; Nátr, 2005). Climate change is a key issue of our time. It is necessary to constantly monitor the production of greenhouse gases (GHG) in the world and, at the same time, look for ways to reduce their most important resources. Agriculture should also

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participate in reducing the emission load within the trend of sustainability (Niggli, 2011; West, Marland, 2002). Therefore, it is desirable to find the possibilities of emission savings when growing crops for energy purposes.

The LCA method (Life Cycle Assessment) may be used to monitor specific emission loads of different farming systems (Brentrup, 2004; Kočí, 2009). This method assesses the environmental impact of a product based on the assessment of the material and energy flows, that the monitored system shares with its surrounding environment (Haas, Wetterich, Geier, 2000; Brentrup, 2001). It is a transparent scientific tool (Weinzettel, 2008) which evaluates the environmental impact on the basis of inputs and outputs within the production system (Greadel, Allenby, 2003). On the basis of this study, it is possible to make a model of the production system, identify the strongest sources of emissions from various energy flows, determine the overall emissions load within the maize production and the emission load corresponding to a certain amount of methane.

MATERIAL AND METHOD

The aim of this paper was to provide information about the impact of the emission load on the environment produced during the cultivation of maize. The simplified method of Life Cycle Assessment (LCA), defined by the international standards of ČSN EN ISO 14 040 (CNI, 2006a) and ČSN EN ISO 14 044 (CNI, 2006b), was used as a tool to calculate the emission load. The results of the study were related to *the Climate change impact category*expressed in the carbon dioxide equivalent (CO_2e = 1x CO_2 + 23x CH_4 + 298x N_2O). The SIMAPro software and the ReCiPe Midpoint (H) method were used for the calculations. 1 kg of a final product, i.e. 1 kg of dry matter of maize (hereinafter DM = dry matter and GM = fresh weight) represented the functional unit of the system. Technological process of the production of silage maize intended for the production of biogas in BGS was compiled based on primary data (data for practical experiments of ZF JU inČeské Budějovice), as well as secondary data (acquired from the Ecoinvent database, literature search and normative data on agricultural production technologies). The database uses data geographically related to central Europe. The primary data were collected between 2012 to 2014 and the secondary data between 2000 - 2014.

The life cycle modelling includes the farming phase (field emissions, seeds and seedlings, fertilizers, plant protection products, agrotechnical operations). The load from infrastructure (farm buildings, machinery, processing infrastructure, means of transport) was not included in the life cycle and the data were not assessed. Manure at 40 $t \cdot ha^{-1}$, urea ammonium nitrate at 149.5 $kg \cdot ha^{-1}$ (a pure form of nitrogen), triple superphosphate at 30 $kg \cdot ha^{-1}$ (a pure form of phosphorus) a potassium nitrate at 50 $kg \cdot ha^{-1}$ (a pure form of potassium) were applied to fertilize.

Besides the emissions arising from the inputs mentioned above, so called field emissions (N_2O emissions) are also produced after the application of nitrogen fertilizers. The IPCC methodology (*Intergovernmental Panel on Climate Change*) is used to quantify them (De Klein et al., 2006). For the purposes of this assessment, screening tests indicating methan yields were also performed from the samples of corn silage. On the basis of detected values, it was possible to determine the emissions load at a profit of 1 liter of methane.

RESULTS AND DISCUSSION

The article assesses the selected technological process of corn growing in order to produce biogas in BPS. The results show the amount of emissions released into the environment and are related to *The Climate change impact category* which is expressed in the carbon dioxide equivalent (CO_2e = 1x CO_2 + 23x CH_4 + 298x N_2O). The same concentrations of various greenhouse gases has very different consequences for the increase in absorption of longwave radiation. This means that certain greenhouse gases are more potent than others (Watson et al., 1990; Watson et al., 1992; Flessa et al., 2002). Moreover, these gases (CO_2, N_2O, CH_4) are characterized as greenhouse gases with a direct impact on the climate (Smith, 2008). The most potent greenhouse gass from agriculture is nitrogen monoxide (N_2O) (Mosier et al., 1998; Smith et al., 1997). One kilogram of this gas has the same greenhouse effect as 289 kg of CO_2 (Nátr, 2005).

Table 1 shows the values of various system processes included in the calculation. The highest emission load is associated with the application of fertilizers (0.06810 kg $CO_2e \cdot kg^{-1}$ DM). The mineral nitrogen fertilizer (0.04264 kg $CO_2e \cdot kg^{-1}$DM) and mineral nitrogen fertilizer, which produces so-called field emissions of N_2O (0.05519 kg $CO_2e.kg^{-1}$ DM), have the largest share. For example, Rochette et al. (2008) states in his publication that the use of mineral nitrogen fertilizers is the major source of emissions (primarily N_2O) in agriculture and one of the most nitrogen-doped plants is maize (Millar et al., 2010). Agrotechnical operations (distribution of manure, medium deep tillage, seedbed preparation, sowing, chemical treatment of crops, application of mineral fertilizers, harvesting, removal of maize from the field, conservation and silage preservation) are other sources of CO_2e emissions which are based primarily on normative fuel consumption(0.02202 kg $CO_2e.kg^{-1}$ DM).

The average yield of 19.25 $t \cdot ha^{-1}$ DM (Maize hybrid with FAO number 310) and the methane yield of 7805.88 l per hectare (which corresponds to 405.5 l methane / $\cdot kg^{-1}$ DM) were achieved based on the selected agrotechnical practises. The harvest took place when the content of dry matter in the phytomass was around 32%, which is generally considered optimal (Amon, 2007). As *table 2* shows, the total emission load of the production of 1 kg DM is therefore 0.14991 kg CO_2e and the total emission load is, at a profit of 1 litre of methane from maize silage, $0.3696 \cdot 10^{-3}$ kg CO_2e. Both figures are related to the production of 19.25 $t \cdot ha^{-1}$ DM per hectare.

Table 1

Production of emissions within particular system processes

Sub-system processes	kg CO_2e $\cdot kg^{-1}$ DM of maize	Share in %	kg CO_2 $\cdot kg^{-1}$ GM of maize
Organic fertilizer	0.02099	14.1	0.00630
Mineral nitrogen fertilizers	0.04264	28.4	0.01279
Mineral phosphatic fertilizers	0.00272	1.8	0.00082
Mineral potassium fertilizers	0.00176	1.1	0.00053
A total of fertilizers	**0.06810**	**45.4**	**0.04496**
Consumption of seeds	0.00280	1.9	0.00084
Chemical protection	0.00180	1.2	0.00054
Agrotechnical operations	0.02202	14.6	0.00661
Field N_2O emissions (converted to CO_2e) arising from tha application of nitrogen fertilizers	0.05519	36.8	0.01655
A total production	**0.14991**	**100**	**0.04496**

Table 2

The total emission load per the production unit (kg CO_2e•kg^{-1} DM and GM kg CO_2e•l^{-1} of methane) and per the area unit (kg CO_2e•ha^{-1})

	Evaluation categories	*Zea mays* L.
1	kg CO_2e ·kg-1 of DM	0.14991
2	kg CO_2e ·kg-1 of GM	0.04496
3	kg CO_2e $\cdot l^{-1}$ of methane	$0.3696 \cdot 10^{-3}$
4	kg CO_2e $\cdot ha^{-1}$	$2.8856 \cdot 10^{3}$

As mentioned above, the highest emission load is associated with the application of mineral nitrogen fertilizers (28.4 % of the total production of kg CO_2e $\cdot kg^{-1}$ DM), as well as with the production of field emissions (36.8 % of the total production of kg CO_2e $\cdot kg^{-1}$ DM) which arises from the application of nitrogen fertilizers. Agrotechnical operations represent the share of 14.6 % and the use of organic fertilizer (manure from dairy cattle) 14% of the total production of CO_2e. Conversely, the lowest amount of CO_2e emissions arises from the use of products for chemical plant protection (0.00180 kg CO_2e $\cdot kg^{-1}$ DM) and the use of maize seed (0.00280 kg CO_2e $\cdot kg^{-1}$ DM). These values are rather negligible and it is not necessary to include them in the overall assessment (Kramer, Moll, Nonhebel, 1999).

Due to the efforts to mitigate the climate change, it is essential to identify cost-effective ways of avoiding greenhouse gas emissions. The agriculture is regarded like a significant producer of emissions and there are opportunities to mitigate their rise. Speaking of reductions (i.e. mitigation) in CO_2e production within the chosen cultivation process, it is necessary to focus especially on two of the strongest sources (application of nitrogen fertilizers and field emissions arising after the application of nitrogen fertilizers). These are produced within the agricultural processes most (Zeijts van Leneman, Sleeswijk, 1999). (Zeijts, van Leneman, Sleeswijk, 1999). In this regard, the issue of reduction in the dose of fertilizers and the total change of the agricultural system is often discussed (Moudrý jr. et al., 2013). Another way to reduce greenhouse gas emissions is the replacement of maize by different energy crops. These may be, for example, energy grasses which are also suitable because of their favorable properties (Amon, Kryvoruchko, Amon, 2004), although may not fully replace maize (Grieder et al., 2011). Nevertheless, energy grasses may produce a lower amount of CO_2e emissions due to the nature of perennial plants and generally lower fertilizer requirements during their life cycle.

CONCLUSION

The results show that the total emission load resulting from the cultivation of maize intended for the production of biogas during the selected growing cycle is 0.14991 kg $CO_2e \cdot kg^{-1}$ DM of maize. This corresponds to the value (0,140870 kg $CO_2e \cdot kg^{-1}$ DM) of the standard technological process in the cultivation of maize for BGS in the Czech Republic (BERNAS et al., 2014). The highest emission load is associated with the application of nitrogen fertilizers (0.04264 kg $CO_2e \cdot kg^{-1}$ DM) and the field N_2O emissions arising from the application of nitrogen fertilizers (0.05519 kg $CO_2e \cdot kg^{-1}$ DM) within the Climate change impact category. Reduction in the doses of mineral fertilizers and replacing them with organic fertilizers (manure) within the maize production for energy purposes may result in the lower production of CO_2emissions (even at the cost of lower yields) . Another way to reduce the amount of greenhouse gases emissions (CO_2e) may be the change of cultivation technology or to include other energy crops suitable for these purposes. When deciding whether to introduce other energy crops suitable for the production of biogas, it is also necessary to know the CO_2e emissions load emerging during the growing cycle. Consequently, it may be possible to carry out further assessment and comparison.

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