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Evaluation of methane production from maize silage by harvest of different plant portions

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ABSTRACT

Biogas production is mainly based on the anaerobic digestion of cereals silages and maize silage is the most utilized. Regarding biogas production, the most important portion of the plant is the ear. The corn ear, due to high starch content, is characterized by a higher biogas production compared to the silage of the whole plant.

In this paper, we present the results of experimental field tests carried out in Northern Italy that aim to evaluate the anaerobic methane potential (BMP) of different portions of ensiled maize hybrids. The BMP production is evaluated considering the possibility of harvesting and ensiling: the whole plant; the plant cut at 75 cm of height; the ear only; the plant without the ear. For the different solutions, the results are reported as specific BMP and as average biogas production achievable per hectare. The methane production by harvesting and ensiling the whole plant (10,212 and 10,605 $m^3\ ha^{-1}$, for maize class 600 and 700, respectively) is higher than the ones achievable by the other plant portions (7961 and 7707 $m^3\ ha^{-1}$, from the ear; 9523 and 9784 $m^3\ ha^{-1}$, from the plant cut at 75 cm; 3328 and 3554 $m^3\ ha^{-1}$, from the plant without the ear, for maize class 600 and 700, respectively). The harvest of the whole plant, although it is the most productive solution, could not be the best solution under an economic and environmental point of view. Harvesting only the ear can be interesting considering the new Italian subsidy framework and for the biogas plants fed by biomass transported over long distances.

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1. Introduction

The agricultural contribution to greenhouse gases (GHGs) emissions is undeniable [1]. Agricultural activities play a significant role in increasing the concentration of GHG in the atmosphere and, hence, agriculture contributes to global warming and climate change [2]. The two most important GHGs emitted by primary sector are methane from livestock breeding and nitrous dioxide from fertilizer application [3]. In

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Europe, agricultural activities are responsible for 10% of the total GHG emissions (about 405 $MtCO_2eq$ per year). Nitrous oxide emissions (from fertilizer application as well as from manure management) represent approximately 210 $MtCO_2eq$, while methane emissions (from enteric fermentation, manure management, and rice cultivation) account for about 195 $MtCO_2eq$ [4].

The reduction of fossil fuel consumptions and the mitigation of greenhouse gases (GHG) emissions are both key issues for a sustainable development. In this context, the renewable energy generation can help meet both these ambitious targets. In Europe, the generation of energy from renewable sources is increasing thanks to energy policies (i.e. EU target of 20% renewable energy by 2020) [5,6].

The EU objectives can be met by the development of all the different renewable energy sources [6,7]. Among these, the biogas has proved to be interesting for energy generation in rural areas in particular, when the generated energy is locally used [7–10].

In Italy, during the past 15 years, biogas production from anaerobic digestion of agricultural biomasses has considerably increased. Nowadays, more than 1000 agricultural biogas plants are running, mainly in the northern regions [11]. In 2011, 3405 GWh of electricity were generated from biogas [12] with an increase of 65% in respect to 2010. At the end of 2012, the installed electrical power was 756 MW and 1.65% of the Italian electric consumption was produced from agricultural biogas plants. Most of these plants operate in co-digestion and, consequently, are fed with energy crops (mainly cereal silage), agricultural by-products (animal sewage) and residues from agro-industry [3,11,13–15].

Strong public incentives were granted for electricity produced from biogas, especially for the AD plants put into operation before 31 December 2012 and with electrical power lower than 1 MW. 280 € MWh^{-1} of electricity was the fixed incentive for the electricity fed into the grid, with no consideration regarding by-product utilization for feeding and heat valorisation. The public incentives framework for electricity production from biogas has been updated with the D.M. of 6 July 2012 [11]. In general, the incentives (€ MWh^{-1}) have been strongly reduced (15–35%) and more importance has been paid, by means of the introduction of bonus, to the heat valorisation and by-products utilization. From the 1 January 2013, the highest incentives (236 € MWh^{-1}) are granted to small plants (electrical power < 300 kW) mainly fed with by-products (minimum 70% of the biomass introduced into the digesters).

As a consequence of the new incentive framework, the ratio between the mass of by-products and silages must be carefully evaluated. In Northern Italy, the most widespread agricultural by-products are pig and cow slurries [9,11,12,14,15] that are characterized by low specific biogas productions (380–450 $m^3\ t^{-1}$ of volatile solid for pig slurry and 300–360 $m^3\ t^{-1}$ of volatile solid cow slurry) [16–18] (approximately 6–25 times smaller than maize silage) [19,20]. The feeding of the AD plant with these slurries only, allows getting the highest subsidy but, on the other hand, it requires to build big digesters with higher costs and it can involve long transport distances for the feedstock. When the biogas plants are built for the valorisation of animal slurry available on the farm, the co-digestion with feedstock characterized by high energy density (e.g. example cereal silage) allows to maximize the electrical CHP power and to achieve the highest incentive.

On the other hand, it must be considered that, over the years, the spread of biogas plants often concentrated in specific areas resulted in the growth of the biomass transport distances and of the feedstock prices.

Currently, biogas production is mainly based on the anaerobic digestion of cereals silages [3,21–23]; among these, maize silage is the most utilized [24]. Maize hybrids are the most used crops for energy production [13,25,26]; they can be grown as a single crop system or, after the harvesting of winter crops (e.g. wheat or triticale), as a double crop system. Regarding the biogas production, the most important portion of the plant is the ear. The corn ear represents a very good feedstock for biogas production because, due to the high starch content, it is characterized by a higher biogas production compared to the silage of the whole plant. However, detailed information about the biogas production of the different plant portions is lacking both concerning specific production (m^3/kg) and global production (m^3/ha).

In this paper, we present the results of experimental field tests carried out in the Po Valley (Northern Italy) to evaluate the anaerobic methane potential (BMP) of different plant portions of ensiled maize hybrids. The BMP production is evaluated considering the possibility to harvest and silage: (1) the whole plant; (2) the plant cut at 75 cm of height; (3) the ear only; (4) the plant without the ear. For the different solutions, the results are referred both to their specific BMP and to the average biogas yield achievable per hectare.

2. Methods

2.1. *Experimental field*

The experimental field tests were carried out on a farm sited in the district of Lodi (Lombardy Region), a region located in the middle of the Po valley (45° 60′–44° 77′ lat. N, 7° 65′–12°22′ long. E). This valley is surrounded by high mountains (Alps and Apennines) and it is characterized by good water availability. Although the precipitation regime has two minima in summer and winter the irrigation systems (lakes, rivers, canals, ditches) guarantee a good water supply also in summer.

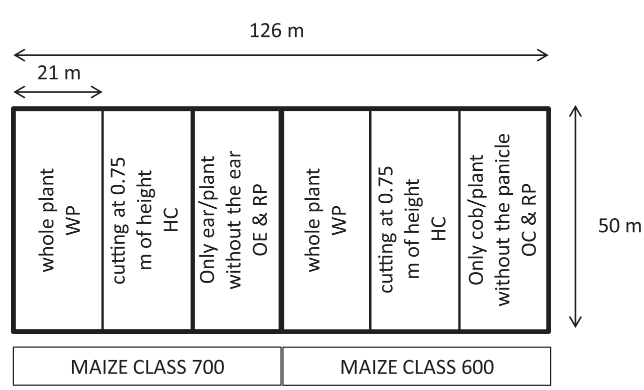

Fig. 1 – Subdivision of the experimental field.

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