BIOMASS AND BIOENERGY 63 (2014) 321–329

Available online at www.sciencedirect.com

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Biomethane production from different crop systems of cereals in Northern Italy

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ARTICLE INFO

Article history:
Received 16 July 2013
Received in revised form
21 January 2014
Accepted 31 January 2014
Available online 28 February 2014

Keywords:
Biogas
Anaerobic digestion
Energy crops
Anaerobic biomethane potential
Italy

ABSTRACT

Global warming is linked to the reduction of green house gas emissions (GHG). The anaerobic digestion of animal manure and energy crops is a promising way of reducing GHG emissions.

The increasing number of biogas plants involves a high consumption of energy crops and the needed of big agricultural area. In Italy, cereals silages are the main feedstock for biogas production and are commonly grown under two different crop systems: single crop (only maize) and double crops (maize later winter cereals).

In this paper we present the results of experimental field tests carried out by monitoring the anaerobic biomethane potential (BMP) of different cereals silages commonly grown in the Padanian Plan.

A laboratory device has been developed to measure the specific biomethane production of the different cereal silages. The different energy crops have been evaluated, in single and double crop systems, expressing the biomethane production per hectare.

The maize hybrids show higher specific biomethane potentials respect to winter cereals. Maize FAO class 700 achieves the highest production per hectare as a single crop. Nevertheless, the highest biomethane productions per hectare are reached with double crop system in particular when maize FAO class 500 follows triticale (+12% respect the best single crop system).

1. Introduction

Renewable energy generation is increasing thanks ambitious energy policies such as the EU target of 20% renewable energy by 2020 come into effect. Agricultural biogas is one such source. Biogas has proved to be interesting for energy generation to rural areas when used locally [1]. Nevertheless, energy production from biogas must occur in a sustainable framework. Concerning this over the years several studies have been carried out and different methodologies have been developed [2–4].

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0961-9534/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biombioe.2014.01.041

Agricultural biogas plants can be fed with energy crops (mainly cereals) but also with agricultural by-products (animal sewage) and residues from agro-industry [5–7].

The use of animal sewage as a raw material for biogas production had been strongly encouraged in the last years by the guidelines for energy, environmental and agricultural policies set out in all the norms whose final objectives were: (i) decreasing air and soil pollution linked to sewage disposal [8]; (ii) producing good quality amendment from by-products; (iii) increasing the amount of energy deriving from renewable sources by using the simple technology already existing on site. This led to a global reconsideration of all animal dejections which, from refuse, became a resource both from the environmental and the economic point of view [9–11]. As consequence of this, and thanks to the strong contribution of small agricultural biogas units which started taking advance of the co-digestion of dedicated energy crops, in 2011, biogas produced 35.922 TWh of electricity in Europe [8]. Manure is an easily available resource on farms, but the limited production rate, the low biogas yield and high investment cost do not make the production of biogas from manure economically feasible without adequate support [12]: as a matter of fact, if we consider that the anaerobic digestion of the sole animal dejections hardly ever allows farmers to reach 150–200 kW of installed power, it is clear how the improvement of co-digestion of animal manures with energy-rich co-substrates such as energy crops or, rather, with agroindustrial by-products and other biodegradable wastes has an increasing attractiveness [13,14] effectively enhanced by the incentives provided [15].

With reference to Italy, it is doubtless that the history of livestock breeding goes together with the history of livestock breeding in the Po Valley and, in particular, with that of the Lombardy Region which is the undisputed leader in this sector [11] with many big intensive livestock farms spread on the territory. Also for the Regional policies, Lombardy is actually the Region with the highest number of biogas plants in Italy with about 370 fully working units (with an average electric power of 714 kW) and where energy crop production is still nowadays based on traditional cropping systems for fodder production and silage conservation, whose technologies are already available in farms. Overall in Italy there are 994 anaerobic digestion plants for a global power of 757 MW. In the 2011, Italy, with 3.405 TWh of electricity produced from biogas, was the third European producer after Germany (19.426 TWh) and United Kingdom (5.735 TWh) and ahead of France (1.196 TWh) and Netherlands (1.027 TWh) [8].

Currently, biogas production is mainly based on the anaerobic digestion of cereals silages (maize, wheat, triticale and sorghum), grass silages, grain crops and agroindustrial waste. Energy crops are the most commonly used substrates and have already been studied for their use in biogas processes [7,16–20] or in the framework of different energetic approaches [5,21]. In Lombardy, 600–700 FAO class maize hybrids are the most used crops for energy production as single culture system, while 300–400–500 FAO class maize hybrids, after the harvesting of winter crops like wheat or triticale, can be suitable if the double culture system is chosen.

Over the years, the spread of biogas plants, often concentrated in specific areas (such as the provinces of Cremona, Lodi and Mantua), resulted in the growth of concerns about the fact that more and more agricultural land is tilled for feeding the digesters. In 2013 growing seasons, about 10% of the overall Italian maize area (approximately 10,000 km^2) [22] is earmarked to biogas production. This issue has been reported in all the other European countries where agricultural biogas production is widespread. In Germany, in 2011 about 650.000 ha were specifically grown for biogas production [19]. The reduction of agricultural land used to feed the digester can be achieved mainly by increasing biogas production per hectare.

In this paper we present the results of experimental field tests carried out by monitoring the anaerobic biomethane potential (BMP) of ensiled crops commonly grown in the Padanian Plan evaluating them both as single and double culture systems and with reference both to their specific BMP and to the average biogas yield achievable per hectare of surface. The aim of the study is to evaluate the most productive crop systems for biogas production as well as to provide useful information about the most important cereals used to feed the digesters. The achieved results can be useful not only for Northern Italy but also for all the areas characterized by temperate climate in which biogas plant are fed with cereals silages.

2. Methods

2.1. Crops

All the farms where field tests were carried out are placed in Lombardy Region (Italy), located in the Po valley (45° 60′–44° 77′ lat. N, 7° 65′–12°22′ long. E). This plan can actually be described as a large basin surrounded by high mountains (Alps and Apennines) and opened only toward East which causes it to be exposed to winter cold outbreaks of polar continental air (mainly coming from Siberia) while Alps and Apennines protect the area from the influence of Mediterranean and Central Europe Climate. As consequence of this, the climate of the Po Valley is a climate of transition between the Mediterranean climate, dominated by anticyclonic patterns and the Central European climate (Koeppen's Cfb), dominated by the oceanic influence of westerlies. Confirm of this transitional climatic character lies in the precipitation regime that, with two minima (in summer and winter) and two maxima (in spring and fall) is partially opposite in phase with respect to the evapotranspirational request of the atmosphere which has its maximum in summer.

Wheat (*Triticum aestivum* L.), Triticale (× *Triticosecale*) and Maize (*Zea mays* L.) plants were grown (both as single and double crop) in the following farms all placed in Lombardy:

- "*Muraro*" farm (district of Lodi)
- "*Dotti*" experimental farm (district of Lodi)
- "*Eurosia*" farm (district of Cremona).

Both "*Muraro*" and "*Dotti*" farms have medium loam soils while "*Eurosia*" farm soil is sandy loam: at the moment of the experiment all of them had been regularly fertilized and amended for long time with zootechnical sludge.