Sicilian potential biogas production

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Abstract

This study is aimed at predicting the Sicilian potential biogas production, using the Organic Fraction of Municipal Solid Waste (OFMSW), animal manure and food industry by-products, in a region where only one biogas plant using MSW and one co-digestion plant are nowadays available.

The statistical data about OFMSW, the number of animals bred in medium and large farms and the amounts of by-products of food processing industries were evaluated, in order to compute the Sicilian potential biogas and energy production. The OFMSW produced in Sicily, that is 0.8 million tons ca. per year (37% of MSW), could be used in a bio-reactor, together with other raw materials, for Anaerobic Digestion (AD) process, producing biogas and "digestate". Moreover, 3.03 million tons ca. of manure, collected in medium and large animal husbandry farms (where cows, pigs and poultry are bred), and 350 thousand tons ca. of by-products, collected in food processing industries (pomace from olive oil mills and grape marc from wineries), might be used for AD process.

The Sicilian potential biogas production from the AD of the above raw materials is 170.2 millions of m^3, that is equal to 1023.4 GWh of energy per year, of which 484 GWh from animal manure, 303 GWh from OFMSW and 236.4 GWh from food industry by-products. The highest biogas production is in the province of Palermo (35.6 millions of m^3), Ragusa (30.8 millions of m^3) and Catania (22.8 millions of m^3), having a potential energy production of 213.8, 185 and 137 GWh, respectively.

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Introduction

The biogas produced in a reactor at the end of Anaerobic Digestion (AD) process can be used for the extraction of methane, that can be transferred to the natural gas distribution pipeline or used as vehicle fuel. Another option is to transform the biogas produced into electric and/or thermal energy, in order to contribute to replace fossil-oil based energy sources with renewable ones.

Instead, the other product of AD process, that is the digested substrate or "digestate", is generally separated into a solid and a liquid fraction. The solid fraction can be used as an organic substrate for greenhouse cultivation, while, according to the EU Nitrate Directive (91/676/EEC), the liquid fraction having a chemical composition suitable for plant nutrition can be spread on soils as an organic fertiliser (EU, 1991), in order to minimise the applied rates of nitrogen mineral fertilisers (Weiland, 2010).

The AD process is able to significantly reduce bad smells (up to 80%) and positively change the composition of odours (Weiland, 2010), inactivate weed seeds, bacteria (*e.g. Salmonella* spp., *Escherichia coli*, *Listeria* spp.), viruses, fungi and other parasites in the feedstock (Strauch and Philipp, 2000; Sahlström, 2003).

If a mixture of the Organic Fraction of Municipal Solid Waste (OFMSW), animal manure and food industry by-products, eventually together with herbaceous energy plants and other raw materials, are used for AD, the biogas yield can be increased (Piccinini *et al.*, 2008). Investigations and practical experience show that mixtures of industrial organic wastes with agricultural production ones or plant biomass determine the following benefits: to improve the AD process, so that the digestate can be enriched with various compounds having properties more suitable for plant fertilisation; to increase the biogas yield and, therefore, the biogas plant profitability (Navickas *et al.*, 2004, 2005). Furthermore, after the anaerobic co-digestion, it is possible to minimise the problems related to the collection of some wastes (*e.g.* OFMSW, animal manure, sewage sludge, wastes of slaughter houses), *i.e.* bad smell (due to the concentration of proteins and sulphuric compounds) and high nitrogen concentration (Comparetti *et al.*, 2012).

In Sicily (Italy) about 5 millions of inhabitants (ISTAT, 2012) produce about 2 million tons of Municipal Solid Waste (MSW) per year, of which the 37% can represent the Organic Fraction (OFMSW), and the OFMSW treated is only about the 3% of MSW (Sicilian Region, 2011). The OFMSW could be used in a bio-reactor, together with other raw

materials, in order to produce biogas and "digestate", in a region where only one biogas plant using MSW is operating at the landfill of Palermo (Sicilian Region, 2012) and one co-digestion plant is available at Marianopoli (Caltanissetta). Moreover, in Sicily, the manure produced in medium and large animal husbandry farms (breeding cows, pigs, poultry, etc.) and the by-products of food processing industries (*e.g.* pomace from olive oil mills and grape marc from wineries) would constitute the mixture usable for biogas production (Piccinini *et al.*, 2008).

In this perspective the aim of this study is to predict the Sicilian potential biogas production, using the above unmarketable raw materials, *i.e.* OFMSW, animal manure and food industry by-products.

Materials and Methods

The statistical data about OFMSW, the number of animals bred in medium and large farms and the amounts of by-products of food processing industries were evaluated, in order to compute the Sicilian potential biogas and energy production.

The potential biogas production per year from OFMSW (B_{OFMSW}) was determined according to the following equation, based on the biogas yield (b_w) (Bolzonella *et al.*, 2006) and the mass of this fraction produced per year :

$$B_{OFMSW} = b_w \cdot m_w \quad \text{(Eq. 1)}$$

where : b_w is the biogas yield of OFMSW ($m^3 \cdot t^{-1}$);
m_w is OFMSW mass (t).

The potential energy production per year from OFMSW (E_{OFMSW}) was determined according to the following equation :

$$E_{OFMSW} = B_{OFMSW} \quad e_b \quad \text{(Eq. 2)}$$

where : B_{OFMSW} is the potential biogas production from OFMSW (m^3);
e_b is the energetic value of biogas, depending on the methane concentration in biogas ($kWh \cdot m^{-3}$).

In order to determine the potential biogas production from OFMSW, only the 40% of this fraction produced and collected in Sicily was considered to be used for anaerobic co-digestion process.

The mass of manure produced by each animal species was computed by multiplying the mass of manure produced by each animal (Navickas *et al.*, 2009) per the number of cows, pigs and poultry, drawn from the 6th General Census of Agriculture (ISTAT, 2011).

The potential biogas production per year from animal manure (B_m) was determined according to the following equation, based on the biogas yield (b_m) (Navickas *et al.*, 2009) and the mass of manure (m_m) of each animal species :

$$B_m = b_m \cdot m_m \quad \text{(Eq. 3)}$$

In order to compute the potential biogas production from manure, only the manure produced and collected in medium and large farms (having a minimum number of 50 cows or 100 pigs or 1000 poultry units) was considered to be used for anaerobic co-digestion process.

The potential energy production per year from animal manure (E_m) was determined according to the following equation :

$$E_m = B_m \quad e_b \quad \text{(Eq. 4)}$$

where : B_m is the potential biogas production from manure (m^3).

The potential biogas production per year from food industry by-products (pomace from olive oil mills and grape marc from wine making plants) (B_b) was computed using the following equation, based on the biogas yield (b_m) (Piccinini *et al.*, 2008) and the mass (m_b) of each by-product type (ISTAT, 2011) :

$$B_b = b_b \cdot m_b \quad \text{(Eq. 5)}$$

The potential energy production per year from food industry by-products (B_b) was determined according to the following equation :

$$E_b = B_b \quad e_b \quad \text{(Eq. 6)}$$

Results and discussion

In Sicily 5.05 millions ca. of inhabitants (ISTAT, 2012) produce 2.15 million tons ca. of Municipal Solid Waste (MSW) per year, of which 37% (0.8 million tons ca.) can represent the Organic Fraction (OFMSW). At present only 0.07 million tons ca. of OFMSW (3.17% of MSW) are treated (Sicilian Region, 2011), while 315.3 thousand tons per year of this fraction might be used for biogas production.

Moreover, 3.03 million tons ca. of manure, collected in medium and large animal husbandry farms (where cows, pigs and poultry are bred), and 350 thousand tons ca. of by-products, collected in food processing industries (pomace from olive oil mills and grape marc from wineries), might be used for AD process.

The Sicilian potential biogas production is 170.2 millions of m^3, that

Table 1. Mass, potential biogas and energy production from OFMSW, animal manure and food industry by-products, both in the nine provinces of Sicily and in the whole region.

Provinces	OFMSW			Animal manure			Food industry by-products		
	Mass 10^3 t y^{-1}	Biogas 10^6 m^3	Energy GWh	Mass 10^3 t y^{-1}	Biogas 10^6 m^3	Energy GWh	Mass 103 t y^{-1}	Biogas 106 m^3	Energy GWh
Agrigento	26.6	4.3	25.8	52.6	1.3	8.0	47.4	5.0	30.0
Caltanissetta	15.4	2.5	15.0	85.5	2.1	13.0	22.1	2.6	15.6
Catania	75.0	12.0	72.0	302.0	7.8	47.0	31.6	3.0	18.0
Enna	8.6	1.4	8.4	409.3	10.2	61.0	12.7	1.2	7.2
Messina	40.6	6.5	39.0	311.3	7.8	47.0	15.5	1.5	9.0
Palermo	82.1	13.1	78.6	574.2	14.8	89.0	67.6	7.7	46.2
Ragusa	16.4	2.6	15.6	924.8	26.8	161.0	13.2	1.4	8.4
Siracusa	25.1	4.0	24.0	344.6	8.8	53.0	16.4	1.6	9.6
Trapani	25.5	4.1	24.6	28.7	0.7	5.0	124.0	15.4	92.4
SICILY	315.3	50.5	303.0	3033.0	80.3	484.0	350.2	39.4	236.4

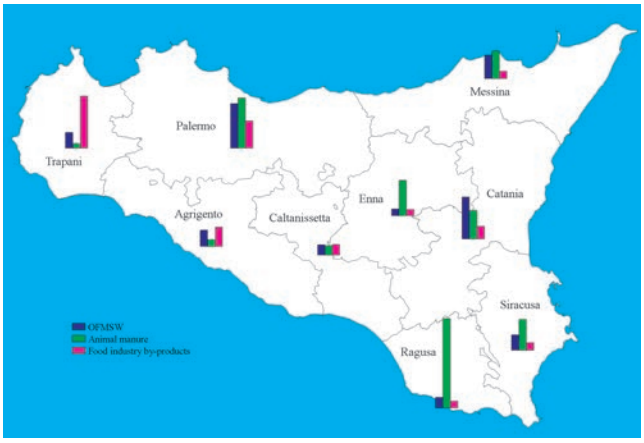

Figure 1. Potential energy production from biogas in the nine provinces of Sicily (GWh).

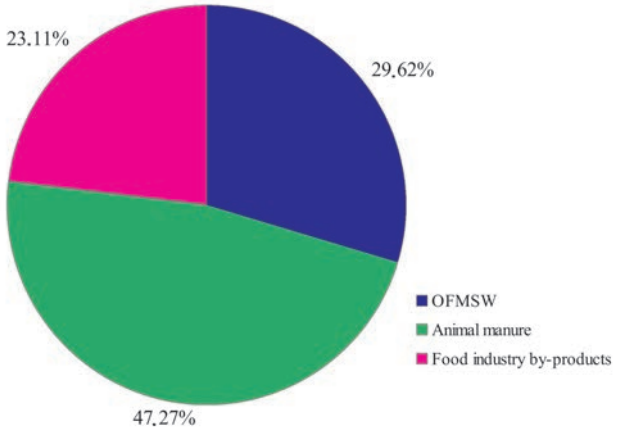

Figure 2. Distribution of Sicilian potential energy production from biogas among the raw materials surveyed.

is equal to 1023.4 GWh of energy per year, of which 484 GWh from animal manure, 303 GWh from OFMSW and 236.4 GWh from food industry by-products.

The highest potential biogas production from the above mixture is in the provinces of Palermo (35.6 millions of m^3, equal to 213.8 GWh per year), Ragusa (30.8 millions of m^3, equal to 185 GWh per year) and Catania (22.8 millions of m^3, equal to 137 GWh per year).

The mass of OFMSW, the manure produced in medium and large animal husbandry farms and food industry by-products, as well as the potential biogas and energy production from these raw materials in Sicily are shown in Table 1.

The potential energy production from OFMSW, animal manure and food industry by-products in the nine provinces of Sicily and in the whole region are presented in Figures 1 and 2, respectively.

The highest potential energy production from OFMSW is in the province of Palermo, due to the highest number of inhabitants and an efficient separate waste collection.

Moreover, the highest potential energy production from manure is in the province of Ragusa, because of the most intensive animal husbandry.

Furthermore, the highest potential energy production from food industry by-products is in the province of Trapani, due to the highest number of food processing industries.

The AD of the mixture surveyed in this study, mainly constituted by animal manure (47%) but also by OFMSW (30%) and food industry by-products (23%), would produce 170.2 million m^3 of biogas, that are equal to 1023.4 GWh per year.

Conclusions

The calculated mass of OFMSW, animal manure and food industry by-products in Sicily is 315.3, 3033 and 350.2 thousand tonnes per year, respectively.

The Sicilian potential biogas production from OFMSW, animal manure and food industry by-products is 50.5, 80.3 and 39.4 million of m^3 of biogas per year, respectively.

The Sicilian total potential biogas production is 170.2 million of m^3 of biogas, that is equal to 1023.4 GWh per year.

The best possibilities for biogas production are in the provinces of Palermo, Ragusa and Catania, having a potential energy production of 213.8, 185 and 137 GWh, respectively.

Waste management is nowadays a problem to be solved in Sicily, as well as in the rest of Italy. In fact, the landfill sites have been or will be filled in with MSW very soon in Italy, where people don't accept the use of new sites in their municipal land. Moreover, the measures aimed at promoting segregated waste collection have been only scarcely implemented in Sicily, as well as in the whole Italy, where the environmentalist movements always fight against the building of incinerators. Therefore, the inefficient waste management has often caused public health problems in whole cities, like recently in Palermo.

In this perspective politicians should promote the valorisation of organic wastes (*e.g.* OFMSW, animal manure and food industry by-products) through AD process. In fact, whether organic wastes were anaerobically digested, it would highly reduce the amounts of these wastes that are nowadays aerobically composted or spread on land as bio-fertilisers after purification or, even worse, landfilled. Therefore, politicians should promote the building of co-digestion plants also in Sicily, in order to contribute to reduce CO_2 emission and, as a consequence, global warming.

References

Bolzonella D., Pavan P., Mace S., Cecchi F. 2006. Dry anaerobic digestion of differently sorted organic municipal solid waste: a full-scale experience. Water Sci Technol 53(8):23-32.

Comparetti A., Greco C., Navickas K., Venslauskas K. 2012. Evaluation of potential biogas production in Sicily. Proceedings of the 11th Int. Scient. Conf. "Engineering for Rural Development", Jelgava, Latvia, 24-25 May, pp. 555-559.

European Union, 1991. Council Directive 91/676/EEC concerning the protection of water against pollution caused by nitrates from agricultural sources. In: Official Journal of the European Communities, 12, pp 1-8.

ISTAT - National Institute of Statistics. 2011. 6th General Census of Agriculture. Sicilian Region.

ISTAT - National Institute of Statistics. 2012. We Italy, 100 statistics to understand the country in which we live. pp. 1-13.

Navickas K., Župerka V., Venslauskas K. 2004. Bioduju gamyba iš organiniu atlieku ir kulturiniu augalu. Šilumos energetika ir technologijos, KTU, pp. 277-282.

Navickas K., Venslauskas K., Župerka V. 2005. Pieno produktu gamybos atlieku anaerobinis perdirbimas. Žmogaus ir gamtos sauga. LŽUU, pp. 46-48.

Navickas K., Venslauskas K., Zuperka V. 2009. Potential and possibilities of biogas production from agricultural raw materials in Lithuania. Rural Development 2009. Lithuanian
University of Agriculture, pp. 365-369.

Piccinini S., Bonazzi G., Fabbri C., Sassi D., Schiff M., Soldano M., Verzellesi F., Berton M. 2008. Energy from biogas produced from livestock manure, dedicated biomass and wastes. Funded by the Autonomous Region Friuli Venezia Giulia, Rural Development Programme 2007-2013, pp. 1-21.

Sicilian Region, Department of Water and Wastes. 2011. Waste Report 2011.

Sicilian Region, Department of Energy. 2012. Energy Report 2011. Energy data in Sicily, pp. 1-122.

Sahlström L. 2003. A review of survival of pathogenic bacteria in organic waste used in biogas plants. Bioresource Technol 87:161-6.

Strauch D., Philipp W. 2000. Hygieneaspekte der biologischen Abfallbehandlung undverwertung. In: Bidlingmaier W. (Ed.) Biologische Abfallbehandlung, Eugen Ulmer, Stuttgart, Germany, pp. 155-208.

Weiland P. 2010. Biogas production: current state and perspectives. Appl Microbiol Biot 85:849-60.