POULTRY MANURE GASIFICATION AND ITS ENERGY YIELD

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Înlăturarea şi depozitarea deşeurilor rezultate de la păsarile de curte reprezintă una din principalele probleme din sectorul dedicat gestionării acestor tipuri de deşeuri. În cadrul acestei lucrări sunt prezentate rezultatele obţinute în urma realizării unor teste realizate într-o instalaţie pilot de gazeificare. Obiectivul lucrării este de a realiza o analiză preliminară pentru energia rezultată în urma tratării deşeurilor de la păsări prin gazeificare. Este de asemenea prezentat nivelul producţiei de energie şi a gazului de sinteză rezultat în urma procesului. Rezultatele obţinute sunt considerate a fi satisfăcătoare, ceea ce ar încuraja şi o posibilă aplicare a tratamentului la scară reală.

The disposal of poultry manure is one of the main problems of the poultry sector. The results of some tests developed in a gasification pilot plant are presented in this paper. The aim was to preliminarily analyze the energy generation from poultry manure treated by gasification. The level of energy yields and the quantification of the produced syngas are also reported. The good results suggests an possible application at full scale.

Keywords: energetic yields, gasification, poultry manure.

1. Introduction

In Italy the poultry industry has an important role in the sector of agriculture. It is estimated that 50 million hens are present, while poultry meat production exceeds one million tons by year. The poultry farms are not uniformly distributed, but are found mostly in the Northern part. Veneto, Emilia Romagna, Lombardy and Piedmont alone cover 79% of the Italian poultry meat production. For each hen in addition to meat or eggs, it is produced also a certain amount of

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"poultry manure", a waste mainly composed of manure, litter and feathers, with a weight ranging from 4.5 to 45 kg by year depending on the mode of farming.

Historically, manure has been used as fertilizer for agricultural land but, in the last years, taking into account the new legislation and the scientific development, new processes are proposed for the treatment of this poultry manure in order to exploit also its energy yield. One of these processes regards the gasification one.

Modernized biomass gasification for power generation has attracted increasing interests as an attempt to reduce our reliance on fossil fuel. On this matter, the design phase of the plants [1,2,3] and a good knowledge of the current technologies for the gasification is obviously, very important comparing the related yields with those related to coal, oil, gas and waste feedstock gasification [4]. The aim is to follow technical solutions applied with a high suitability level under the technical and economic point of view. Another technical aspect to be focused is the connection with the gas network and biogas utilization system. It is necessary to tackle crucial aspects in light of the new directions in the energy industry, in particular how to integrate fuel processing into contemporary systems like gas power plants [5]. Therefore, this technology is still under development and requires further research and feasibility evaluations [6].

Regarding the experience described in this paper, it is necessary to focus the attention on the management problems in Italy and the characteristics of poultry manure. The disposal of poultry manure is one of the main management problems of the national poultry sector and especially in Lombardy (northern part of Italy, the area with the highest density of population and industrial activities), where large breeding produce great quantity of poultry manure.

Improper management of manure has resulted in environmental problems such as surface water eutrophication, ground water pollution, and greenhouse gas emissions. There are a lot of technical alternative manure management scenarios aiming at energy and nutrient extraction (i.e. thermal pretreatment, anaerobic digestion, anaerobic co-digestion, liquid/solid separation, drying, incineration and thermal gasification) [7, 8, 9].

The current practice that sees the spreading of poultry manure on cropland is losing more and more consistency and applicability because of the economic burden of the practice, with possible repercussions on the cost of producing the final chain product [10, 11]. All this is in contrast to a total production of poultry manure that has values of absolute importance [12, 13]. Moreover, the Nitrates Directive (91/676/CEE), concerning the amount of nitrogen that can go in agriculture, has strongly changed the poultry manure utilization.

Taking into account these new limits, the poultry manure that is a special waste, can be used for energy recovery (within the scope of the DM 5/2/98) in certain conditions (Lower Heating Value, LHV > 8,000 kJ kg^{-1}; limits for Cu, Cd, Pb and Ni) in plants that have thermal input of not less than 6 MW.

In Fig. 1, the situation of poultry manure in Lombardy is presented [8]. In addition, in Table 1 breakdown obtained through a literature data analysis in relation to dry samples is presented.

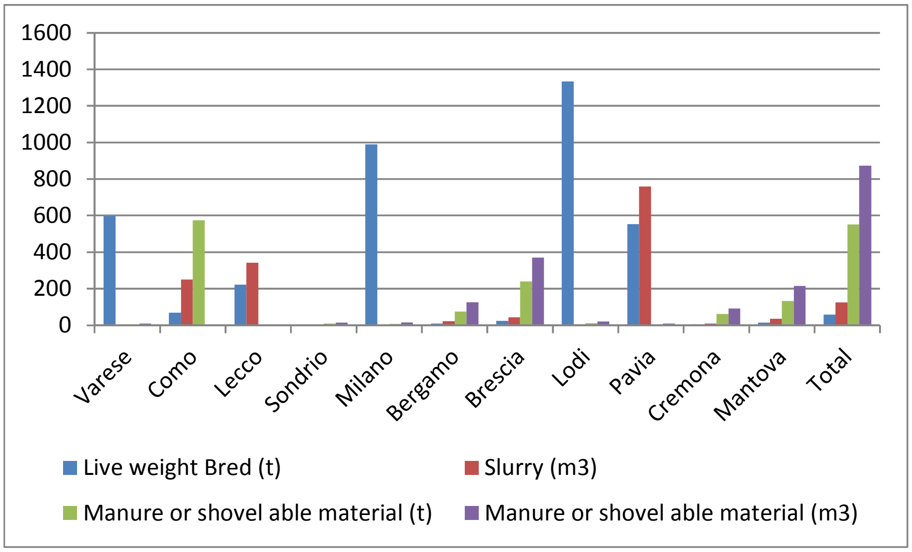

Fig. 1. Poultry manure production in Lombardy

Table 1

Average values refer to analytical dry sample [10]

Variable	Units	Value
Ash	(%)	27.15
Higher Heating Value	kJ kg^{-1}	12.793
Lower Heating Value	kJ kg^{-1}	11.761
Carbon	(%)	35.39
Hydrogen	(%)	4.86
Nitrogen	(%)	5.90
Sulphur	(%)	0.34
Oxygen	(%)	26.36
Chlorine	(%)	< 0.3
Arsenic	mg kg^{-1}	0.97
Cadmium	mg kg^{-1}	0.48
Chromium	mg kg^{-1}	13.36
Copper	mg kg^{-1}	117.36
Mercury	mg kg^{-1}	< 0.2
Manganese	mg kg^{-1}	537.38
Nickel	mg kg^{-1}	7.71
Lead	mg kg^{-1}	1.16

However, the presented poultry manure composition is an average one, and depends strongly on the origin of the biomass (laying-hens, breeders, turkeys, etc.). The ash from manure treated by gasification can be considered also as an opportunity to use it in agriculture. The ash would be characterized by a significant presence in terms of nutrient (i.e., potassium, phosphorus) with low heavy metals (i.e., cadmium, chromium, copper, nickel and zinc) as the technical literature reports [14, 15].

2. Materials and methods

For the development of the research, the following data from full-scale plants were used:

- 1 MWt corresponding to about 3,000 t per year of poultry manure;
- 2 MWt (6,000 t per year);
- 4 MWt (12,000 t per year);
- 6 MWt (18,000 t per year).

The tests were developed in a gasification pilot plant. The thermotechnic process consisting of incomplete oxidation of treated biomass at a high temperature (800-1000°C), with a lack of oxygen for the production of a syngas, composed of H_2, CO, CxHy, N_2, CO_2.

The pilot used plant is characterized by the following components of system:

- ***hopper load:*** the system load, it must be airtight. An external input of atmosphere or air would cause uncontrolled combustion of matrix in its treatment phase and of syngas with results that could also be dangerous. The whole system is controlled by the load weighing belt that, once set, shall adjust the speed and thus the flow of incoming material.
- ***gasifier tunnel:*** the gasifier consists of a pair of coaxial cylinders, of which the hollow interior rotates and the outer disk is fixed. In the cavity between the two, flames develop. By induction, heat passes to the inner chamber where the material is placed. A series of vanes oriented, supported by the rotary motion, allows the progress of the matrix inside the tunnel. The internal temperature is constant, apart from the very first section, connected to the system load. The end of the tunnel has two openings, one on the top and other in the bottom, respectively, which make possible the extraction of syngas and the unloading of solid residue (ash and dust). After the start-up, combustion is fed from the syngas produced.
- ***fumes purification system***: the fumes leaving the gasifier are made up of syngas, still with a significant presence of fine dust. To deal with the flow and to use the syngas is preferred to adopt the solution of the cyclone separator for dust suppression. The cyclone is insulated to maintain a high temperature,

preventing condensation of moisture mixed with the syngas. In addition to dust, other contaminants are present in the syngas. A scrubber uses a basic solution and can eliminate the presence of sulphur oxides, while washing with a solution of urea reduces the concentration of nitrogen oxides.

- ***post combustion:*** the post combustion chamber allows the destruction of organic compounds transforming them into CO and CO_2. The dwelling time is about two seconds, so as to prevent the formation of PCDD/Fs (Polychlorinated dibenzodioxins and furans) while still providing a diminution of organic pollutants over 99%. After the start-up, the fuel used is the syngas produced by the process.
- ***electric generator:*** there are several ways to produce electricity from the combustion of syngas, being able to use a combustion engine, a gas turbine (with relatively high calorific value of syngas) or a steam turbine. There are also systems of combined gas and steam turbines. In this case the electric power generator is a steam turbine. Before reaching the heat exchanger, the fumes from the burner are used to produce steam to power a turbine. The system produces electricity used to serve the needs of the entire system.
- ***heat exchanger:*** the heat exchanger consists of a series of tubes through which the fumes from the combustion process (750 °C) pass. The external cold air is preheated by passing from the outside air temperature to 350 °C. Because of the sharp drop in temperature in the scrubber, the syngas must also be heated, thus reducing the energy requirements of the post combustion chamber. The fumes heat up the cold air drawn from outside destined to feed the dryer and the post combustion chamber. The fumes are conveyed to the chimney at a temperature of about 200 °C.
- ***discharge of solid waste:*** collection is via a device with two openings, one at the top and one on the bottom of the hopper. Once the waste collection chamber is full, the upper door closes and automatically the lower one opens which allows the emptying of the chamber. This precaution is necessary to prevent syngas to dissipate outside and for air to enter the gasifier with the effect of significantly reducing the yield of the process.
- ***detection systems:***
  - syngas composition analysis: automated analyzer with dual analysis system, cell IR (NDIR) and electrochemical cells. Continuous sampling of CH_4, H_2, CO, CO_2, O_2, NH_3 and H_2S;
  - analysis of air emissions: continuous concentrations of CO, CO_2, SO_2 and NOx. The sampling probe is placed on the discharge chute.
- ***energy yields:*** the energy yields are related to the composition of the syngas produced. The higher the component composed of hydrocarbons, the higher the energy density of the syngas. The higher the temperature and dwelling time, the lower the percentage of moisture and greater the energy yield of

syngas. The yields, therefore, depend on the type of matrix, the temperature and residence time in the gasification tunnel, as well as the moisture present.

In order to load the gasifier a piston that pushes the poultry manure inside a hermetically closed system is used. The loading system consists of a conveyor weighing belt, which is entrusted with the task of regulating the speed and frequency of the piston pushing the hopper. The manure must have input humidity between 25% and 35%.

The process has brought to power an average of 300 kg h^{-1}, with peaks of 400 kg h^{-1}. In Fig. 2 the diagram of the pilot plant is shown.

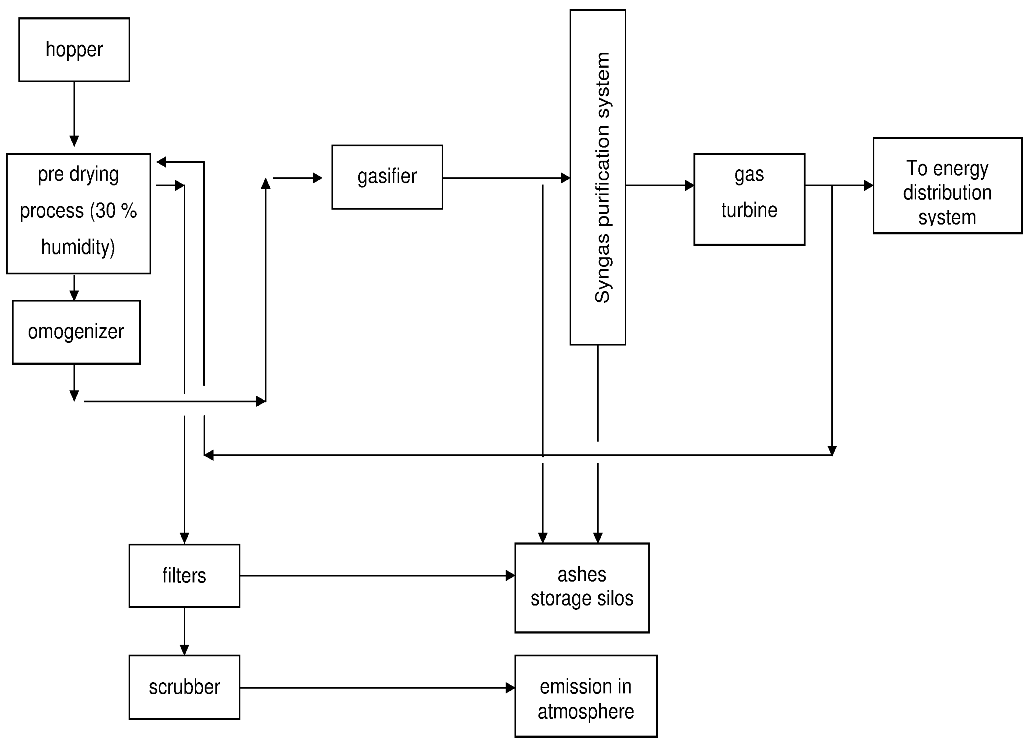

Fig. 2. Process diagram

3. Results and discussion

Several tests with different ranges and average results obtained are shown in the Table 2. The gasification of poultry manure showed a good energetic performance and could be implemented at real scale.

Table 2

Table of experimental tests with average data recorded.

Operating conditions		
	Units	Value
Matrix (substance, source)	Poultry manure	
Average flow rate	kg h^{-1}	300
Dwelling time	h	2
Rotation speed	turns min^{-1}	2
Gasifier temperature	°C	750 – 800
State of matrix (substance) at insertion (entrance)		
Humidity before dryer	%	55
Humidity input gasifier	%	30
Syngas / cycle		
Syngas flow	m^3	332
Mass syngas	kg	265
CH_4	%	75.7
O_2	%	3.9
CO_2	%	11
CO	%	3.04
Ashes produced		
Ashes	kg	40
Amount of ash compared to the load input to the gasification	%	12
Energy yields		
Conversion with single generator (gas turbine)	%	29.8
Electric power produced /cycle	kWh	654.2

4. Conclusions

The disposal of poultry manure is one of the main problems of the poultry sector. The experience reported, regards a gasifier pilot plant fed by poultry manure. The tests were done with a pilot plant in order to assess the level of energy yields and to quantify the synthetic gas that can be produced. In particular, using only poultry manure as feeding matrix, with a soft pre-treatment upstream, it was obtained more than 300 m^3 of syngas (CH_4 = 75%) starting from an inflow of 300 kg h^{-1}, with an interesting energetic yield (>650 kWh of produced by gas turbine/cycle).

Considering the large availability of poultry manure in the northern part of Italy and the good results obtained at the pilot scale in terms of energetic yields (and low percentage of waste to be disposed – only 12% of produces ashes respect the inflow mass), an application at the full scale is going to be studied.

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