COMBUSTION OF POULTRY DERIVED WASTES FOR SMART ENERGY RECOVERY

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Abstract
Due to the stringent and explicit European environmental legislation about land spreading of nitrates, the direct land application of the poultry litter is not anymore the most appropriate disposal technique. We investigated the combustion of pure common poultry derived wastes and mixtures of these with olive pomace in a domestic burner optimized for wood pellet combustion. Typical waste and product streams based on combustion tests were characterized for the different mixtures (100%w to 50%w poultry litter content). We observed that the high CO emissions compared to wood pellet combustion but can be reduced by optimizing combustion; the size distribution function of particle is not influenced by poultry litter content; the inorganic elements are mainly concentrated in ashes.

Introduction
Currently, due to the stringent and explicit European environmental legislation about land spreading of nitrates, the direct land application of the poultry litter is not anymore the most appropriate disposal technique [1]. Composting is an alternative to direct land application, which results in reduced volumes for disposal, improves consistency of waste, and the elimination of pathogens, although additional equipment and handling costs are incurred and the problems of nutrient run off and heavy metal contamination remain [2, 3]. Nevertheless, scientists and poultry industry leaders are being challenged to find alternative ways of managing poultry litter [4, 5]. Many possible alternatives have been investigated and attempted. All have some merit, but one very good solution is utilizing poultry litter as a fuel to generate clean, renewable energy [6]. In such a context, the Italian situation is undergoing a juridical battle in considering poultry litter as a Biomass as done in the European Community law of 2009 for energy production. The question is to consider or not this waste as a biomass for energy production. Setting aside the political and juridical debate, a poultry litter facility is being built in Umbria region of Italy by the Novelli Group. The objective of the technology based on fluidized bed is to manage a large quantity (5 t/day) of poultry litter producing an efficient and economical operation, while keeping low emissions. The worldwide past experiences regarded the commissioning of large power plant fuelled by poultry litter and then presented important problems of soil contamination, bacteriological management of the areas and pollution due to the

waste transportation [7]. In alternative, according the recent European guide lines concerning the smart grids, the generation of electricity and heat from poultry derived wastes based on high-temperature thermal destruction techniques, i.e. combustion, could be a promising local waste management solution [8, 9]. An extensive and interesting review of the recent large-scale power plants fuelled by poultry litter present in Europe is presented by Florin et al [10]. Nevertheless, there remain technical and operational challenges associated with the processing of poultry wastes due to the variability of the waste stream and high costs in comparison to direct land utilization. With the increasing tendency for energy generation from renewable sources and the anticipated introduction of more stringent environmental legislation, we contend that combustion will become economically viable option in the future. Opportunities for improving the economic viability also exist with the co-combustion and/or gasification of poultry derived waste with other agricultural and forestry wastes. In this paper we investigate combustion of pelletized common poultry derived wastes (i.e., manure, bedding and a mixture of these with olive pomace).

Waste preparation

We used the waste production of a medium scale breeding settled in Italy as a representative basis for estimating the potential for energy production from poultry litter. The best solution was to pelletize the raw material. This generated a high versatility of the fuel; it can be easily produced and stocked on-site before being burnt. In this study we used a simple wood pellet machine. Poultry litter (moisture 35 %wt) was preliminary mixed with olive pomace (moisture 5%wt) before being pelletized. Blends containing up to 70%wt of poultry litter were prepared. Higher poultry content lead to a squashy product definitively not suitable for the whole process management. Moreover, the mechanical properties of the so-prepared pellet were not satisfactory and they did not allow the pellet to be correctly fed by the screw conveyor. Then, further experiments were performed on the optimization of the mechanical properties of the blends. The best conditions were obtained with a moisture content of 10 %wt in the poultry litter. Blends from 100%wt down to 50%wt of poultry litter were then possible with satisfactory feeding to the burner. The characteristics of the different blends (Poultry Litter PL/Olive Pomace OP) are presented in table 1.

Table 1. Average composition and chemical properties of the pellets.

	pellet 100%PL	*pellet 70%PL*	*pellet 60%PL*	*pellet 50%PL*	*Pellet 100%OP*
Gross heat value, kcal/kg	3,198	3,895	4,064	4,407	4,931
Net heat value, kcal/kg	2,834	3,350	3,455	3,963	4,752
Moisture, %wt	10	8	8	8	5
Ash content(dry basis), %wt	27	23	17	15	4
C %wt	34.8	39.6	41.1	45.0	51.8
H %wt	4.26	4.91	4.88	5.52	6.22

N %wt	1.79	1.38	1.41	0.91	0.59
O %wt	43.7	44.5	44.9	42.7	39.2
S %wt	0.65	0.63	0.61	0.60	0.51
Cl %wt	0.87	0.90	0.84	0.70	0.52
Ca ppm	74,879	38,427	27,596	20,405	2,348
K ppm	37,675	27,395	24,296	18,986	12,154
P ppm	16,454	10,014	8,369	5,733	541
Mg ppm	6,067	3,857	3,203	2,372	221
Na ppm	3,981	2,522	2,087	1,458	58
Al ppm	2,799	2,255	1,370	1,230	271
Fe ppm	1,657	1,161	889	802	513
Mn ppm	622	399	315	168	10
Cu ppm	280	118	100	69	12
Zn ppm	322	252	174	117	6
Ba ppm	29.7	50.4	22.8	14.3	4.0
Cr ppm	22.2	13.3	14.0	17.8	1.6
Co ppm	3,2	1,9	1,5	1,1	0.1
Ni ppm	10.3	5.7	6.0	7.3	2.1
V ppm	9.8	6.6	5.2	3.7	0.3
Na+Ca+K+Si+Mg+Cl, %wt	13.13	8.12	6.56	5.02	2.00

Combustion results

Experimental set-up

The experiments were performed in a 50 kW house-built pellet burner inserted in a water-cooled closed fire-place. The pellets were fed to the burner head by mean of two screw conveyors. The pellet flow rate was kept constant for all the experiments. The energy exchanged to cooling water was kept constant. The combustion air was also kept constant and was fixed to the oil pomace value in the electronic remote control. The burner parameters were previously optimized for the oil pomace combustion. The objective of this paper is to compare combustion performances of the different pellets keeping constant the combustion parameters. During the experiments the exhaust gas temperature and the stable gases concentrations (CO, CO2, NO, SO2) were continuously measured. Sampling was performed tree times for each blend in order to measure the average concentration and the size distribution of the particles. The determination of the particulate matter was performed according to the EN 13284-1:2003. Isokinetic sampling was performed at the exhausts of the boiler and the samples were size-segregated by means of an 8-stages Andersen impactor. No dioxin analysis was performed due to its time consuming procedure not compatible with laboratory scale. Finally, a complete chemical analysis of the ash was performed after each run.

Test results

The first comment regards the ignition of the pellet. Only pellets for blends up to 50%wt of poultry litter (PL) can normally ignite, while higher PL content in the pellets generates smoke without ignition. Combustion of 100%wt PL pellet was possible but it suffered from coarse stability. On figure 1.A-D are represented the observed flame for 100%wt PL, 70%wt PL, 60%wt PL, and 50%wt PL respectively.

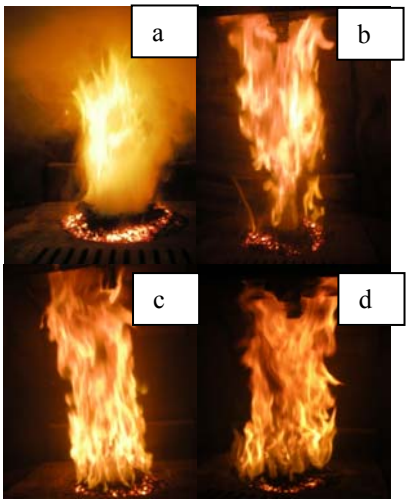

Figure 1. Flame aspect for the different poultry litter content: 100%wt PL (a), 70%wt PL (b), 60%wt PL (c), 50%wt PL (d).

We can clearly observe from the figure 1 that the flame intensity increases while decreasing the poultry litter content. For PL content higher than 60%wt we have a large presence of smoke around the flame; and we can note a more important ash accumulation in the bed of the burner. The combustion performances were followed by continuously sampling exhaust gas. The time evolution of the CO, NOX, O2 concentrations are presented in Figure 2. All the results are on dry basis.

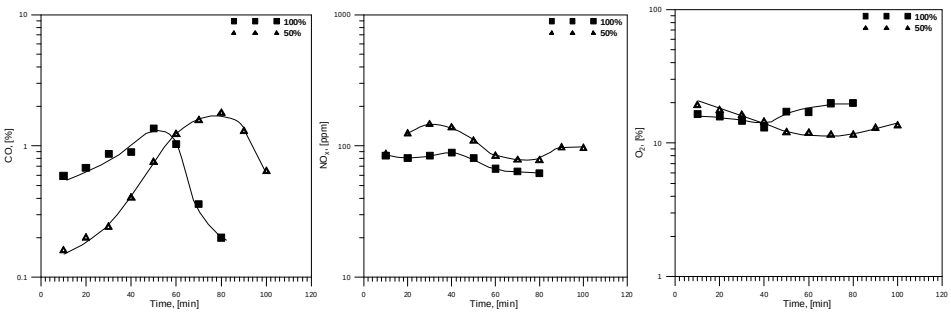

Figure 2. Time evolution of CO, NOx and O_2 concentration for different PL content in pellet.

SO_2 concentration measurements are not presented, since the recorded value never passed over 15 ppm. This is probably due to the chemical boundary of sulfphur inside the poultry litter. The concentration of sulfphur present in the poultry litter is mainly concentrated in ashes [11, 12]. Temporally evolutions of the exhaust gas temperature for the different cases are presented in Figure 3. This figure confirms that the quality of combustion is getting worse as increasing poultry litter content in the pellet. The temperature range is consistent with those found in similar systems [13, 14]. The mean values of CO, NOX and exhaust gas temperature were calculated over 1 hour of combustion and compared to the Italian regulation considering two cases: Power, 150>P≥35 kW and P<35 kW. The results are resumed in Table 2. The overall results about CO and NOX emissions are much higher than those for wood pellet in similar burner [13-16]. This lead to two considerations to reduce these emissions: to lower poultry litter content in pellet or to optimize the combustion parameters. If we compare the mean values to the Italian regulation for both cases (P<35 kW and 150 kW>P≥35 kW), we observe that the CO values are higher than the permitted ones. Tests for optimization the poultry litter content and the combustion parameters are under investigation and will be published soon.

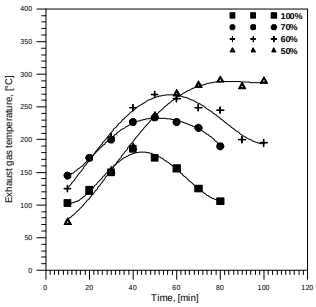

Figure 3. Time evolution of exhaust gas temperature for different PL content in pellet.

Table 2. Mean values over 1 hour of combustion (@11%O_2).

Pellet	CO [mg/Nm^3]	NO [mg/Nm3]	T [°C]
100%PL	18,200	260	140
70%PL	18,400	226	200
60%PL	11,560	190	210
50%PL	11,690	200	230
Limit [a]	5,000	500	-
Limit [b]	350	200	-

a: limit according to Italian regulation for P< 35 kW (UNI-EN-303-5-2004)
b: limit according to Italian regulation for 35≤P< 150 kW (D.L.n.152-2006)

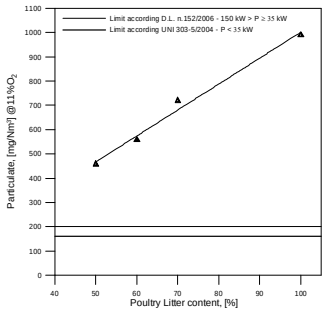

Figure 4. Total Particulate emissions versus the poultry litter content in pellet.

The determination of the total particulate matter was performed for all the cases and the mean values over tree runs normalized at 11% O2 are plotted in Figure 4. The limits for the previously discussed Italian regulations are also showed on the figure. We can observe that the particulate matter (P.M.) concentration linearly increases versus the poultry litter content in the pellet. The values are consistent with similar domestic appliances available in the literature domestic appliances available in the literature [10, 12, 15, 17]. The high concentration values are due to an

important contribution of volatile compounds condensed on solid particles, namely soot particles.

Conclusion

We investigated combustion of pure common poultry derived wastes and mixtures of these with olive pomace in a domestic burner optimized for wood pellet combustion. Typical waste and product streams based on combustion tests were characterized for the different mixtures (100%w to 50%w poultry litter content). We observed that:

- high CO emissions compared to wood pellet combustion but can be reduced by optimizing combustion;
- high particle emissions compared to wood pellet emissions, the size distribution function is not influenced by poultry litter content;
- inorganic elements are mainly concentrated in ashes;

Further investigation will be performed to optimize the poultry litter content in order to fit European regulation. Preliminary tests not presented in this paper indicate an optimized value of 30%w.

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