Technical and Economic Analysis of the Combustion of Mixed Poultry Litter/ Olive Pomace Pellets for Energy Recovery

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Abstract
According to 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 [1-5]. In this work we set out to investigate the technical and the economic feasibility of the combustion of poultry litter blended with olive pomace in a domestic burner initially designed for wood pellets.

Experimental
Poultry litter (PL) was preliminary mixed with olive pomace (OP) before being pelletized by means of a wood pellet machine. Blends nominally containing up to 70%wt of PL were tested. Higher poultry contents lead to a squashy product definitively not suitable for process management. Due to high ash and moisture content (as much as 35% wt.) the Net Heat Value for PL is only 60% that for OP (11.8 vs. 19.9 MJ/Kg).
Combustion experiments were performed in a 50kW pellet burner inserted in a water-cooled closed fire-place (Figure 1). The pellets were fed to the burner head by mean of two screw conveyors. The flow rate was kept constant at 8 kg/h. The objective is to compare combustion performances of the different pellets keeping constant the combustion parameters (heat exchanged, total combustion air, distribution of primary and secondary air) previously optimized for the OP pellet combustion. Temperature and concentrations of CO, CO_2, NO, SO_2 in the exhaust gas were continuously measured. The particulate matter (PM) content was measured by means of an 8-stages Andersen impactor collecting samples ranging between 0.5 and 20 μm (according to EN 13284-1:2003). Elemental analysis of pellets and combustion ashes was performed by ICP-MS.

Combustion Results
Only pellets with up to 50%wt of PL could be ignited with standard procedure, whereas higher PL contents generated smoke without ignition and, therefore, required an assisted light-off to get to stable combustion. During steady operation

the flame intensity increased while decreasing the PL content (Fig.1), according to the higher Net Heat Value of the pellets. Pellets with PL above 50%wt gave an intense smoke generation around the flame and a high ash accumulation rate in the bed. Ashes contained carbon and significant concentrations of Ca, K, P, Mn, Na, possibly making them valuable as a fertilizer.

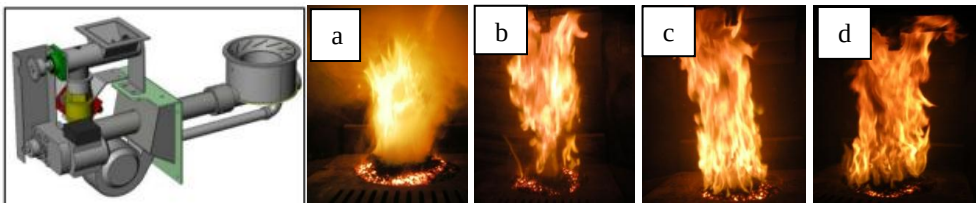

Figure 1: Sketch of the 50kW burner and flame aspect when burning pellets with different poultry litter content: 100%wt PL (a), 70%wt PL (b), 60%wt PL (c), 50%wt PL (d).

The concentration of PM in the exhaust increased linearly with PL content and generally exceeded legislation limits (Fig.2), possibly due to the strong contribution of volatile compounds condensed on solid particles. Elemental analysis of PM mainly showed trace concentrations of Na, Ca, Ba, Zn and Al.

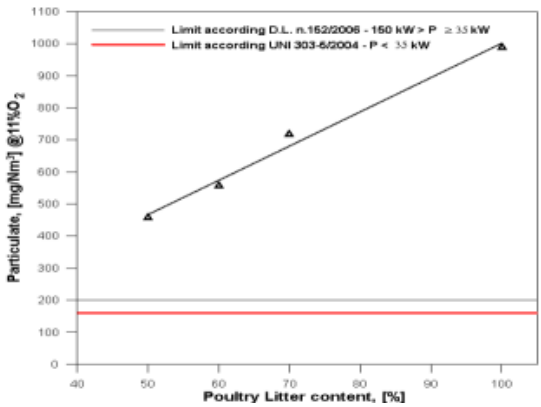

Figure 3: Total Particulate emissions versus the poultry litter content in pellet

Compared to the combustion of wood pellets or pure OP pellets in the same burner, CO emissions were relatively high and again increased with PL content in the fuel. On the other hand NO emissions were less affected by PL content, in spite of 3x larger quantity of fuel bound nitrogen in PL with respect to OP. SO_2 emissions never exceeded 15 ppm. This is probably due to the chemical boundary of sulphur inside the poultry litter, which determines that S is mainly concentrated in the ashes [6,7]. The optimization of combustion conditions in the burner was performed only for 50%PL, since the quality of the combustion worsened progressively for higher PL contents in the pellets. The results are presented in Table 1 in terms of the mean values over 1 h operation in comparison with wood and P pellets [8-11].

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

Pellet	CO [mg/Nm^3]	NO [mg/Nm3]	T [°C]
Wood Class A	320	137	148
Wood Class C	445	228	150
100% OP	690	215	160
50% PL	1160	190	210
Limit	5000[a] (350[b])	500[a] (200[b])	-

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

Economic feasibility of energy generation from poultry litter combustion

The economic feasibility of the thermal energy generation from poultry litter was carried out in the case of a small farm characterized by an annual production of 10^5 birds (675 tons of PL), taking into account the annual costs deriving from the energy demand (heating: $9 \cdot 10^5$ kWh; electricity: $3.5 \cdot 10^5$ kWh) and from disposal of the poultry litter. Two cases were considered: 1) thermal energy is produced using pellets of poultry litter blended with olive pomace, the surplus of poultry litter is externally disposed; 2) thermal energy is produced using conventional fuels and the litter is externally disposed.

Boiler capital costs included costs for gas cleaning units. In particular for the PL/OP boiler, baghouse filters and a wet scrubber were considered [14]. Table 3 presents the main parameters used for the economic analysis. Fixed costs were assumed equal to a Capital Recovery Factor (CRF) taking an economic depreciation and an annual interest rate of 5%. Variable costs included: i) purchase of OP for mixed pellets; ii) disposal of surplus PL; iii) labor costs for boiler O&M.

Table 4 :Main economic parameter values used in the economic analysis

Boilers life [year]	10
Annual interest rate [%]	5
Capital cost of PL/OP boiler plant [k€]	140
Capital cost of Diesel oil boiler plant [k€]	30
Capital cost of LP boiler plant [k€]	25
Capital cost of methane boiler plant [k€]	25
Capital cost of wood pellet boiler plant [k€]	70
Cost of disposal of poultry litter [€/kg]	0.1
Sale price of Olive Pomace [€/kg]	0.1
O&M labor cost for Diesel oil, LP and methane boilers [k€/y]	6.75
O&M labor cost for PL/OP boiler [k€/y]	13.5
Duration of production cycle[h]	1,080

Fig. 4a reports fixed, variable and total costs for thermal energy production using PL/OP pellets vs. the poultry litter content in the pellet. Figure 4b shows a comparison between total costs for energy production using PL/OP pellets and conventional fuels. The use of PL/OP pellets results always cheaper than that of

Diesel oil or LPG, whereas, in the case of methane and wood pellets, costs savings occur for PL contents above 20% and 30% respectively.

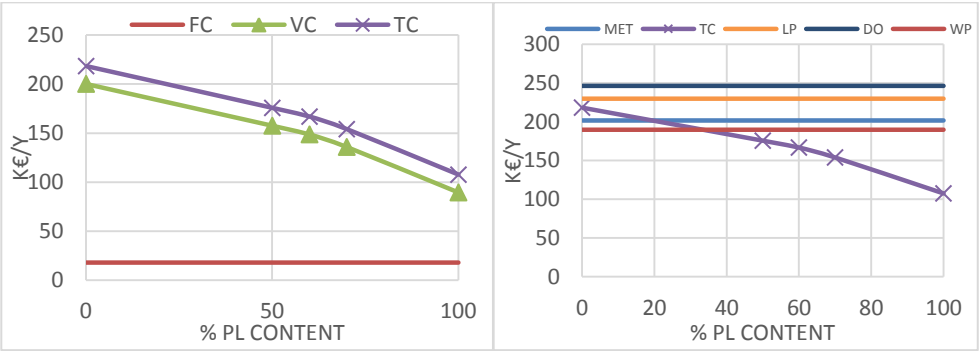

Figure 4 a) Annual costs for thermal heat production vs. poultry litter content in PL/OP pellets: FC=Fixed Cost, VC=Variable Cost, TC=Total Cost. b) Comparison of total annual costs for thermal heat production with conventional (DO: Diesel; MET: Methane; LP: LPG; WP: wood pellet).

Figure 5 reports the comparison of costs for heating energy production between PL/OP pellets and conventional fuels. The general trend is quite similar to that observed for the total annual costs. The specific costs for energy production with PL/OP is always lower than the value calculated when burning methane (60 €/MWh); in comparison to wood pellets, an economic advantage is found for poultry litter content in mixed pellets exceeding ca. 40% wt.

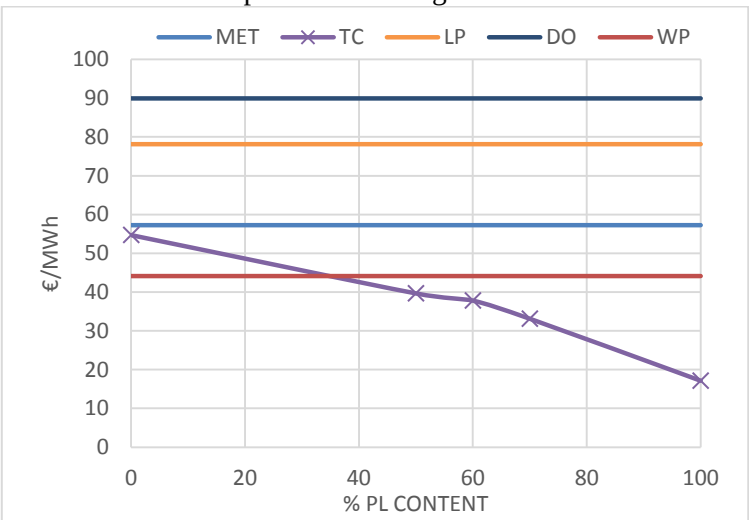

Figure 5: Specific costs for heating energy production by PL/OP pellets (TC) as a function of the PL content in comparison with conventional fuels. DO: Diesel; MET: Methane; LP: LPG; WP: wood pellet.

Conclusion

We investigated the combustion common poultry derived wastes in mixture with olive pomace in a domestic burner initially 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:

- high CO emissions compared to wood pellet combustion which can be reduced by optimizing combustion parameters;
- high particulate matter emissions compared to wood pellet combustion, with a size distribution function not influenced by poultry litter content;

The economic analysis indicated that a concentration of poultry litter for 50% by weight represents a good compromise between the technical feasibility as an alternative fuel and the total costs for heating energy production in the Italian scenario.

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