Potential of Pt-based honeycomb catalyst usage during the pistachio shell combustion

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Unstable situation from the energy pricing in Europe point of view is very discussed topic nowadays (Canepa, 2022). This trend motivates residents of small households use solid fuel combustion appliances more frequently. Several European countries still have not developed sufficient infrastructure for the thermal utilization of solid waste for fulfilment of mandatory European aims (EC, 2014), at the same time. Therefore, huge part of waste is still landfilled or, in case of biomass waste, partly composted (Linden, 2020). Concerning the mentioned ideas, combustion of appropriate waste biomass in modern, small home combustion appliances (especially automatic pellet boilers and stoves) for heating purposes seems to be beneficial. Possible representative of appropriate waste biomass for home utilization occurs to be pistachio hard shells (only hard shell will be considered for this research; further only as PHS).

Simultaneously, the flue gas composition, especially the pollutants formed during the incomplete combustion process (carbon monoxide – CO; organic gaseous compounds – OGC), can be increased by combustion and co-combustion of an alternative fuel, such as PHS in standard small appliances, as was proven in previous study with different biomass-based alternative fuel combustion (Rahib et al., 2019). Possible precaution against the increasing of mass concentration of pollutants from incomplete combustion process in small combustion equipment could be a utilization of oxidation honeycomb catalysts.(Klauser et al., 2018; Reichert et al., 2018).

This study is aimed on determination of possibilities of combustion and co-combustion of PHS with standard wooden pellets in automatic small combustion equipment (originally for standard pellet combustion).

The novelty of the research is in description of the data obtained by combustion tests of previously unexamined material for this purpose in a combination with oxidizing catalyst. For the combustion tests a mix of PHS and standard A1 pellets was chosen in different ratios. PHS composition slightly differs from the pellets, especially from the carbon and ash mass fractions points of view. As the combustion equipment, a prototype of an automatic pellet stove (hereinafter referred to as the stove) with bowl burner was used. For the following experiment a Pt-based honeycomb catalyst provided by Witebeam d.o.o. company was installed at the stove outlet to reduce concentrations of pollutants, especially CO and OGC, in the flue gas. The most important results obtained from combustion tests are shown in Table 1. Overall, 6 separate combustion tests were performed with stabile operation period of 2 hours.

Table 1 Overall results of combustion tests; Note: results of mass concentration of NO_x is recalculated on NO_2; all mass concentrations of pollutants are recalculated for STP conditions and reference volume fraction of oxygen 13 %

Fuel mixture		pellets/ PHS	100/0	90/10	75/25	50/50	25/75	0/100
Heat output		kW	3.8	3.7	3.9	3.6	3.5	3.5
Fuel mass flow		$kg\cdot h^{-1}$	1.21	1.19	1.23	1.23	1.21	1.22
Thermal efficiency (undirect method)		%	65.9	66.7	67.4	64.2	64.5	63.8
Flue gas temperature		°C	257	253	260	255	241	225
Volume fraction of O_2 in dry flue gas		%	15.7	15.6	15.2	15.8	16.0	16.1
Mass concentration of pollutants in dry flue gas (at the catalyst inlet)	CO	mg/m^3_N	513	691	1 475	3 421	4 905	8 871
	NO_X	mg/m^3_N	95	87	125	130	143	134
	C_3H_8	mg/m^3_N	7	16	25	49	71	95
	PM	mg/m^3_N	nd	nd	nd	nd	nd	nd
	CO_2	g/m^3_N	149	148	149	149	148	145
Mass concentration of pollutants in dry flue gas (at the catalyst outlet)	CO	mg/m^3_N	193	364	839	2 683	4 368	8 652
	NO_X	mg/m^3_N	88	81	117	125	139	137
	C_3H_8	mg/m^3_N	6	12	21	39	63	86
	PM	mg/m^3_N	89	303	313	611	952	1 364
	CO_2	g/m^3_N	150	148	152	148	149	146
CO conversion rate of catalyst		%	62.3	47.3	43.1	21.6	10.9	2.5
C_3H_8 conversion rate of catalyst		%	12.7	25.9	16.8	21.5	10.7	9.6

The first test only with wooden pellets was established as a reference and other results of fuel mixtures were compared with it. Despite the lower bulk density of the pellets/PHS mixtures, reaching approximately 43 % for pure PHS in comparison to wood pellets, there were not observed any problems with cumulation of the unburned fuel in the bowl burner, primary optimized and constructed for pellets combustion. Thermal efficiency of the pure wood pellets combustion was 65.9 % (determinated by undirect method). Thermal efficiency of other mixtures reached similar values ± 2 %. During the clear wooden pellets combustion, measured mass concentration of CO was 513 mg/m^3. By gradual adding of PHS into the fuel mixture, there was an obvious increase of this value while the highest value (8871 mg/m^3) was reached during the clear PHS combustion. The same situation occurred from the C_3H_8 mass concentrations in the flue gas point of view. The lowest value (7 mg/m^3) was also reached during the clear wooden pellets' combustion, while by adding of the PHS into the fuel there is obvious increase of this value to the highest reached value (95 mg/m^3).

From the mass concentration of PM point of view (measured only at the catalyst outlet), there was strong correlation between it and mass fraction of PHS in the fuel mixture. The dependency of multiple increase of CO, C_3H_8 and PM mass concentration in the flue gas on combusted fuel mixture is shown in Figure 1.

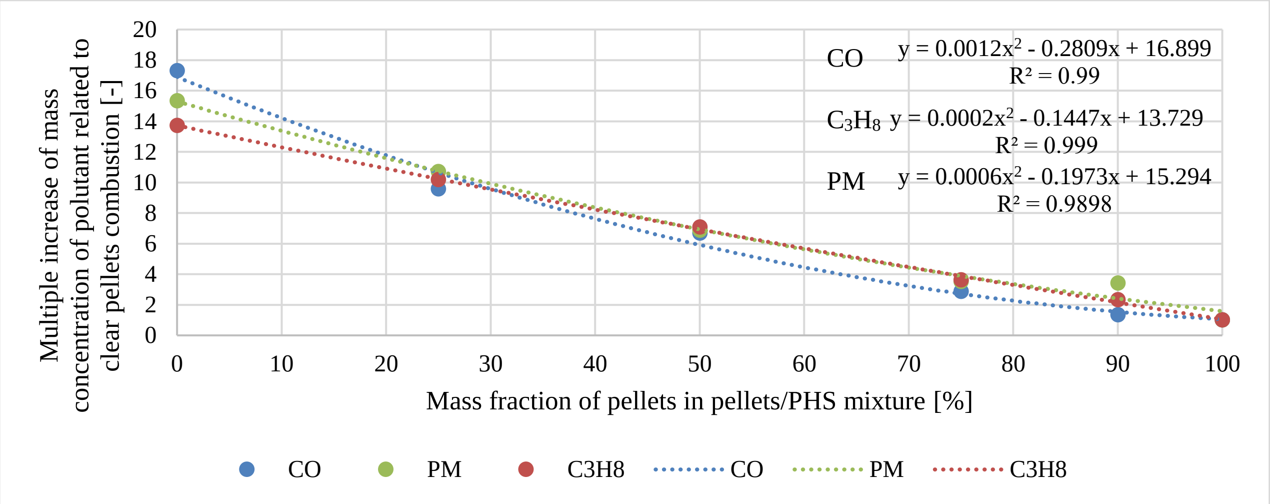

Figure 1 Dependency of multiple increase of CO, C_3H_8 and PM mass concentration in flue gas on fuel mixture

From the NO_x mass concentration point of view, there was a noticeable increase in case of combustion of the fuel mixtures with 25 % of PS and more. The fuel mixture with 10 % of PHS seems to be unaffected.

Relatively low flue gas temperature caused that low conversion rates ranged between 61.3 % and 21.6 %, while flue gas temperatures ranged between 260 °C and 253 °C. For the combustion tests with lower flue gas temperature (mixtures 75/20 and 0/25 pellets/PHS) only negligible conversion rates was reached.

Described data of multiple increase of mass concentration of pollutants as function on mass fraction of pellets in pellets/PHS could be very valuable for manufacturers of small combustion equipment, especially those who use modern technologies. In case of using modern automatic wood pellet stove or boiler with rotational burner, installed catalyst to the higher temperature field of flue gas or installed particulate precipitator could help to reach a reasonable values of mass concentrations of pollutants during the fuel mixture with low mass fraction PHS and high mass fractions of pellets.

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