The use of polymer composites in the deposit from the combustion of briquettes in local heating as an identifier of fuel quality

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Currently, the use of biomass and wood as an energy source is increasing rapidly due to concerns about global warming and the instability of fossil fuel prices. In 2018, biomass accounted for up to 15.2% of household energy consumption in the EU. From one ton of virgin wood, 25 and 35% of sawdust is formed during processing. Wood residues created by cutting and trimming virgin wood are used for the production of chipboard, for the production of wood-plastic composites or energy-efficient pellets and briquettes. For large producers, the waste is usually used directly, mainly as a source of heat for drying. Problematic are small and medium-sized furniture factories and cabinetmaking facilities or sawmills interested in selling "processed waste" at lower prices, which is economically advantageous for local heating in the area. They are usually unaware of the risks associated with the presence of additives in wood products because they are added to the product in low concentrations and are subsequently "diluted" by the addition of "pure sawdust or shavings" and a lower combustion temperature, which does not allow complete thermochemical decomposition of additives. Unconverted parts of chemical compounds or partially decomposed products may be carried away by emissions to ambient air. Adhesives (based on urea and formaldehyde) increase the calorific value of chipboard compared to virgin wood by 3 to 4%, and the amount of ash increases 3-4 times. High temperatures throughout the combustion chamber are required to burn all the hydrocarbons because the wood mass burns with a long flame. Achieving such conditions is almost impossible in small heat sources. Even in areas with the combustion of biomass as the only source of heat, there may be problems with air quality.

The literature lacks information on how to effectively monitor biomass (pellets, briquettes) combustion with the addition of composite waste wood. The presented article aims to provide information for the possible identification of the quality of pellets and briquettes using primary or converted organic compounds, which originated from polymeric materials based on their presence in the sediment from the flue gas paths. This approach is procedurally simpler than measuring emissions, which is time-dependent on the combustion of "unsuitable fuels", while traces of specific organic compounds remain in the sediment longer. The novelty of the article is the verification of the occurrence of organic compounds initially determined in emissions and other combustion products – deposits.

The briquettes were burned in combustion boilers of emission class EC2 and EC3 defined according to EN 303-5 with manual application. Combustion of tracking briquettes in the EC2 boiler results in a deposit of 2.38 ± 0.29 g/kg of fuel, while in EC3 boilers, a three times smaller amount of 0.80 ± 0.12 g/kg of fuel is produced. Deposits from the EC3 boiler contain a higher amount of unburned carbon ($86.2 \pm 1.48\%$) than deposits from the EC2 boiler ($80.2 \pm 3.70\%$). The different conditions during the combustion process in both boilers (temperature) are also confirmed by the mineralogical phase analysis of the deposit. The deposit from EC2 contains $58.5 \pm 2.78\%$ of calcite, while for the deposit from EC3, the content is $25.44 \pm 3.01\%$ (normalized to 100%).

The Py-GC/MS method was used to identify the organic compounds contained in the deposit. The presence of organic compounds derived from the decomposition of phenolic resins (phenol-formaldehyde, PF-R), aminoplasts resins (urea-formaldehyde, resorcinol-formaldehyde, and melamine), polyurethanes and polyvinyl acetate (PVAc), wood glue was detected. Dimethylphenols (3,5-dimethylphenol, 2,5-dimethylphenol) and trimethylphenols (2,4,6-trimethyl phenol, 2,3,5-trimethylphenol) were determined as selective indicators for the presence of PF-R in the original fuel. The presence of UF-R in deposits from a carpentry briquette can be identified by the presence of n, n-dimethylformamide, n, n-dimethylbenzeneamine, methylurea, and urea. Polyurethanes are identified in the deposit by compounds with isocyanates derived from the thermal degradation of PU. Adhesives are an important component of all briquettes. The most commonly used adhesive is polyvinyl acetate, which can be identified in the deposit based on the presence of its most significant deacetylation product, acetic anhydride.

Most wood products contain additives. They can be preservatives that protect the wood against biodegradation or fire; protective coatings give the wood a more favourable aesthetic appearance. Additives improve the durability of the product, eliminate the shortcomings of wood material, or create new types of products in combination with plastics and wood residues. The most important additives include phthalates, which are used as plasticizers. DEHP, dibutylphthalate, and diisobutylphthalate, as well as Kodaflex TXIB nephthalate plasticizers were identified in the deposits. Additives also include flame retardants, which have demonstrated the presence of 2-Propanol, 1-chloro-, phosphate (3:1), and p-Terphenyl. Antioxidants, fungicides and slip additives were also present.

The total amount of identified compounds, which do not come from wood combustion but are the result of optimizing the properties of reagent wood products in the deposit from the boiler EC2 is 6.25 g/kg, and in the deposit from the boiler EC3, it is by about 1/3 less, i.e. 4.25 g/kg. Phthalates (55.5%) and PVAc adhesives (18.6%) are most represented in the deposit of both types of boilers.

The results have shown that although the thermal decompositions monitored by DTA/TG on “pure compounds” show that most of these compounds decompose at temperatures above 500 °C, about 5-7% of the original sample remains undecomposed in the charring reaction. In everyday life and research, the information obtained can be used to identify the fuel burned. It is necessary to determine the use of the right fuels by the combustion plant operator, e.g. when using boiler replacement subsidies (“boiler subsidies”), targeting the overall improvement of air quality, verifying the quality of domestic fuels, etc.