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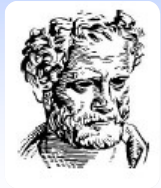

CATEGORIZATION OF ALTERNATIVE FUELS FROM BIOMASS BY-PRODUCTS AND WASTES USING NEW ALTERNATIVE INNOVATIVE TOOLS

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Abstract

The application of the sustainable development agenda leads to a worldwide effort for searching for alternative sustainable fuels. However, in order for the utilization of alternative fuels (e.g. wastes, agricultural by-products, blends of two or more fuels, etc.) to be feasible in the energy market, they should have a label indicating the quality characteristics of the fuel. The purpose of this study is to present new flexible assessment tools for alternative solid fuels and their ashes, (produced from the combustion process), namely, a Fuel Quality Index (FQI), a Fuel Quality Label (FQL), and an Ash Quality Label (AQL). These tools were developed by the authors in order to contribute to the optimal use of waste/agricultural biomass by-products for energy production. To achieve this goal, various waste/agricultural biomass by-products were analyzed by using various techniques such as proximate analysis, calorific value analysis, thermogravimetric/derivative thermogravimetric analysis, ultimate analysis, scanning electron microscope, energy - dispersive spectroscopy, determination of maximum emission factors, ion chromatography analysis, and kinetic modeling. The results of the study showed that the new fuel and ash quality indices take into account not only chemical analyses of the fuels (as presented in some existing fuel quality indices in the literature), but also numerous quality parameters, leading to the innovative and objective expression per produced energy. These tools (FQI, FQL, and AQL) could contribute to the development of the quality standards for alternative fuels, and ultimately contribute to the global efforts for sustainable development.

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Methods

Several agricultural residues -almond shell (ALS), sunflower husk (BSH), sunflower seeds (BSS), sunflower stem, disk florets and seeds (BSW), cob corn (CBC), husk corn (HKC), stalk and husk corn (SHC), walnut shell (WNS), and a lignite sample (as a reference sample), from Greece- were collected and examine via several analytical methods in order to develop three innovative tools for alternative solid sustainable biofuels, such as wastes, biomass residues, composite fuels (blends) etc. All samples air dried, dried in an oven 80 °C for 24 h, and ground (<1 mm) using Retsch SM100 cutting mill. Determination of Gross Calorific Value (GCV) was performed by LECO AC 500, (ASTM D5865-13 standard) [1]. Determination of moisture, ash, volatiles and fixed carbon content was performed with LECO TGA 701 (ASTM D7582 standard) [2]. Thermogravimetric - Derivative Thermogravimetric Analysis (TG/DTG) were performed by a LECO TGA 701 according [3]. Ultimate analysis was performed via an elemental analyzer FlashEA 1112-CHNS according [4] (O=100-C-H-N-S-Ash). Kinetic modelling analysis was performed according [5]. The anion Cl^- was determined by ion chromatography [6]. A FQI was developed using some innovative concepts: a) an additional parameter was considered (activation energy), b) different optimum and maximum values were selected, c) the C, N and S content were expressed as emission factors, d) all other parameters (except for activation energy and GCV) were expressed per produced MJ (by dividing with the experimental GCV), and e) 1/GCV was used a parameter instead of GCV. Several slagging and fouling indices were modified (taking into account GCV, ash content, and standard value of ash/GCV) order to create a total Ash quality Index and ash quality label [6].

A FQL is proposed in order to categorize the fuels in classes according to their FQI values. The class "A" characterize the solid fuels with the best fuel characteristics, and the class "G" characterize the fuels with the worst fuel characteristics.

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Results

Main results of the study are presented in Table 1 Table 2, and in Figures 1 to 3.

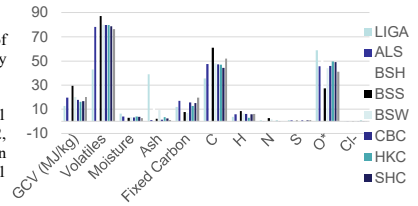

Fig. 1. GCV and proximate analysis results

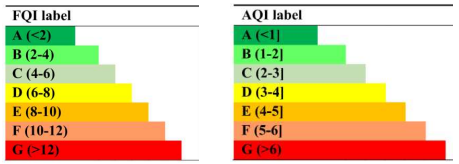

Fig. 2. FQI and AQI guide for the proposed evaluation tools

Table 1. Parameters quality index results [4]

Sample ID	Moisture /MJ	Ash /MJ	1 /GCV	Cl /MJ	E (kJ/mol)	gCO_2 /MJ	gNO_2 /MJ	gSO_3 /MJ
LIGA	1	7.96	0.68	0.03	0.42	0.96	0.93	0.98
ALS	0.1	0.09	0.26	0.01	0.67	0.7	0.05	0.5
BSH	0.72	1.55	0.3	0.75	0.34	0.53	0.63	0.33
BSS	-0.21	0.14	0.01	0.02	0.02	0.47	1.21	0.21
BSW	0.02	1.16	0.24	0.42	0.12	0.67	0.98	0
HKC	0.23	0.54	0.43	0.46	0.86	0.92	0.03	0.67
SHC	0.17	0.33	0.4	0.81	0.39	0.97	0.52	0
WNS	-0.08	0.11	0.24	0.02	0.48	0.8	-0.01	0.61

Table 2. FQL and AQL results

Sample ID	FQL	AQL
LIGA	G	D
ALS	B	C
BSH	C	C
BSS	A	C
BSW	B	E
HKC	C	C
SHC	B	C
WNS	B	B

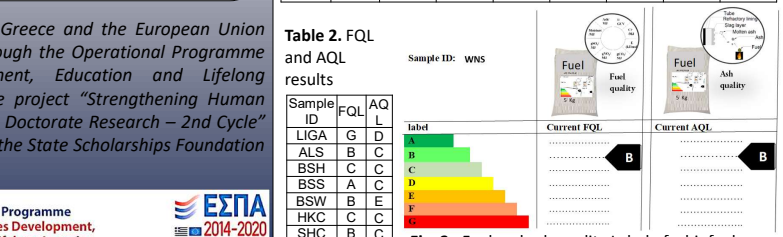

Fig. 3. Fuel and ash quality Label of a biofuel. Results of the analyzed Walnut shell (WNS).

Conclusions

Three novel tools -fuel quality index (FQI), a total ash quality index (tAQI) and fuel quality label (FQL)- were developed, in order to compare/classify alternative solid biofuels resulted from biomass residues/wastes within the concepts of sustainable development and circular economy. The FQI was developed using novel concepts: a) expressing the parameters, involved in the calculation of indices in normalized values in terms of produced megajoule, and b) the fuel quality parameters, were not only chemical composition characteristics (as in the literature) but also combustion characteristics of a fuel, such as. activation energy resulting of kinetic modelling.

The results of this study showed that the total Ash Quality Index and the total Ash Quality Label can summarize easily all the major information that is derived from each of the slagging / fouling indices and these tools could help to easier comparison and categorization of ash-related problems among several solid fuels.

The fuel quality index, the ash quality index, and the fuel quality label could enhance the use of agricultural residues/Wastes-to-Energy worldwide and support agricultural residues to entering as new solid biofuels to the energy market.

Bibliography

1. ASTM International, 2013. ASTM D5865-13 Standard Test Method for Gross Calorific Value of Coal and Coke. ASTM International, West Conshohocken, PA.
2. ASTM International, 2015. ASTM D 7582-15 Standard Test Methods for Proximate Analysis of Coal and Coke By Macro Thermogravimetric Analysis. ASTM International, West Conshohocken. PA.
3. Iordanidis, A., Asvesta, A., Vasileiadou, A., 2018. Combustion behaviour of different types of solid wastes and their blends with lignite. Therm. Sci. 22 (2), 1077–1088.
4. Vasileiadou, A., Zoras, S., Iordanidis, A., 2021. Fuel Quality Index and Fuel Quality Label: Two versatile tools for the objective evaluation of biomass/wastes with application in sustainable energy practices. Environmental Technology & Innovation 23, 101739.
5. Vasileiadou, A., Zoras, S., Iordanidis, A., 2021. Biofuel potential of compost-like output from municipal solid waste: Multiple analyses of its seasonal variation and blends with lignite. Energy 236, 121457.
6. Vasileiadou, A., Papadopoulou, L., Zoras, S., Iordanidis, A., 2022. Development of a total Ash Quality Index and an Ash Quality Label: Comparative analysis of slagging/fouling potential of solid biofuels. Environmental Science and Pollution Research 29(28), 42647-42663.