RESEARCH OF Na*, K*, AND Ca* FLAME EMISSION DURING A SINGLE BIOMASS PELLET COMBUSTION

M. Sadeka[1], N. Striūgas[1], M. Rabaçal[2], M. Costa[2]

1. *Lithuanian Energy Institute, Laboratory of Combustion Processes, Breslaujos str. 3, LT-44403 Kaunas, Lithuania.*
2. *IDMEC, Mechanical Engineering Department, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal*

ABSTRACT

This study focuses on the measurement of Na*, Ca*, and K* emission during the combustion of single biomass pellets doped with different amounts of Na, Ca, and K using a spectroscopy method. In this work, wood and straw pellets are compared. A biomass washing and soaking procedure was used to demineralize and to dope the biomass samples with different concentrations (0.5%, 2%, 5%) of Na, Ca, and K. The biomass pellets were suspended in a natural gas flame. Temperature was measured with a thermocouple placed inside the biomass pellet. Optical bandpass filters were mounted in an ICCD camera and the emission intensity in the corresponding wave lengths was recorded with the Andor software. The results show that the emission intensity of K was dramatically reduced after applying the washing procedure to the straw samples. The results show that it is possible to identify the combustion period from the temperature measurements and from the emission profiles of the minerals.

Keywords: Potassium, Calcium, Sodium, Chemiluminescence, Biomass, Combustion

1. INTRODUCTION

During the last decade, the use of biomass for heat and power production became very important. With the increase of the biomass usage, the quality of the feedstock for energy production becomes an issue when the feedstock variety increases. During the thermal degradation of biomass, a number of chemical or physical transformations occur, and it is not easy to forecast the whole combustion process when the change of fuel composition varies. The combustion of agro-biofuels poses a significant challenge due to the typically high amount of ash, specifically alkali chlorides, which may lead to the corrosion of the boiler's surfaces. The characteristics of biofuels influence directly the combustion process and ash slagging problems can occur [1-4]. Furthermore, the fly ash deposited on the heat transfer surfaces of the boiler furnace reduces the boiler's efficiency. The moisture content, ash content and particle size are some of the main biomass characteristics that determine the quality of combustion [2]. In particular, the potassium content in the biofuels is an indicator of the formation of deposits in the surface of the boiler [3,4].
K-emission spectroscopy has been used to measure the emission of potassium during the combustion of pine, eucalyptus, wheat straw, rape straw, miscanthus, olive residue, and willow doped with different concentrations of potassium [5,6]. It was found that the emission of potassium can be directly correlated with the combustion stages, namely devolatilization and char combustion [5]. Potassium is not the only problematic inorganic, others include sodium and calcium [2]. The emission of sodium and calcium has not received attention in

corresponding author: M. Sadeckas, Marius.Sadeckas@lei.lt

the past and more studies are required. Under these circumstances, the aim of the present work is to investigate the chemiluminescence phenomenon from Na*, K*, and Ca* during the combustion of single wood and straw pellets with different concentrations of Na, K and Ca.

2. MATERIALS AND METHODS

2.1 Biomass

In this work, two solid fuel types, namely wood and straw, were used and compared. The biomass pellets were subjected to a procedure to remove the ashes and impregnated different quantities (0.5%, 2%, 5%) of Na, K, and Ca. The washing and doping procedure consists of using HNO_3 acid for the washing procedure and adding the required concentration of minerals for doping the samples. Figure 1 shows the alkali content found in the original samples, and in the samples before and after the washing and the doping procedure.

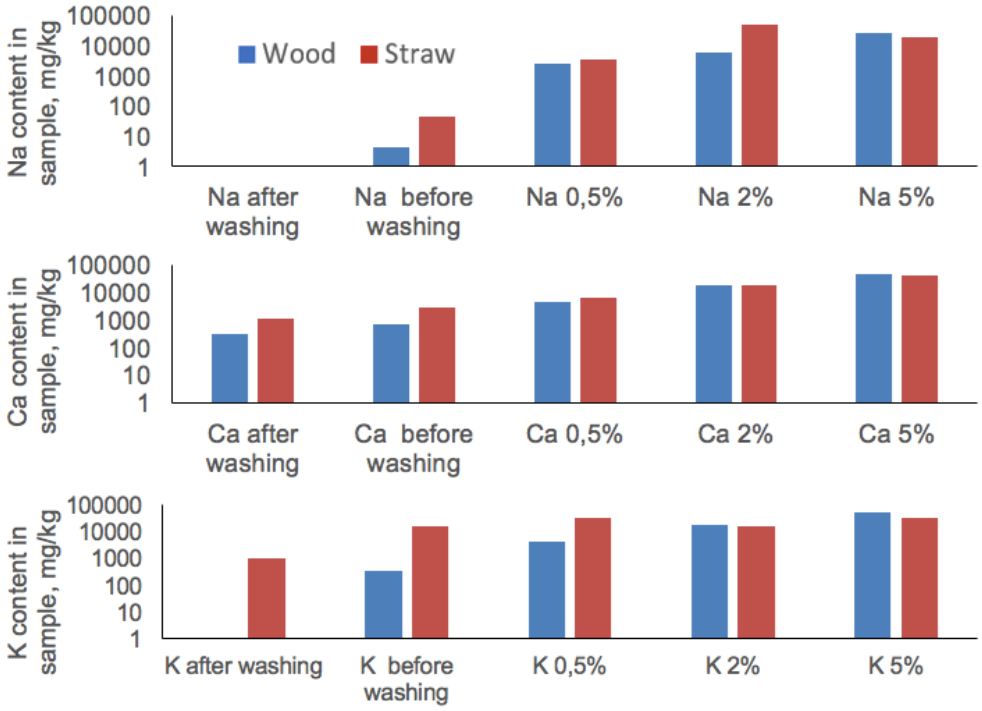

Figure 1. Alkali content measured in the original samples, and in the samples before and after the washing and the doping procedure.

2.2 Experimental setup

Figure 2 shows the experimental setup. The biomass pellets were placed within a natural gas flame. The pellets' internal temperature was measured with a thermocouple mounted inside the biomass pellet. Optical bandpass filters were mounted in an ICCD camera and the emission intensity in the corresponding wave lengths was recorded with the Andor software. The optical bandpass filters used in this work were 770 ± 2 nm for K*, 590 ± 2 nm for Na*, and 620 ± 2 nm for Ca*.

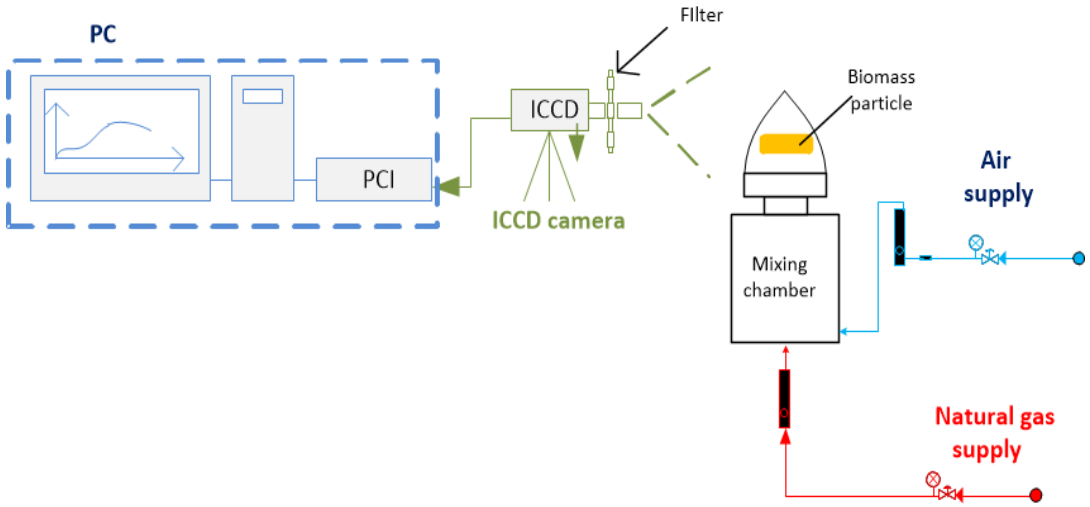

Figure 2. Experimental setup.

3. RESULTS AND DISCUSSION

Figure 3 shows the internal temperature of the pellets before and after the washing procedure during combustion. In the case of the biomass before washing, it is possible to identify that the combustion process starts around 100 s in the case of the wood and around 75 s in the case of the straw, given the steep increase of temperature. Two stages are identifiable, the first corresponding to the first most intense peak of temperature, and the second corresponding to the second less intense peak of temperature. After washing, the peaks occur later and with a lower magnitude, indicating that the ashes present in the original sample catalyze the combustion process.

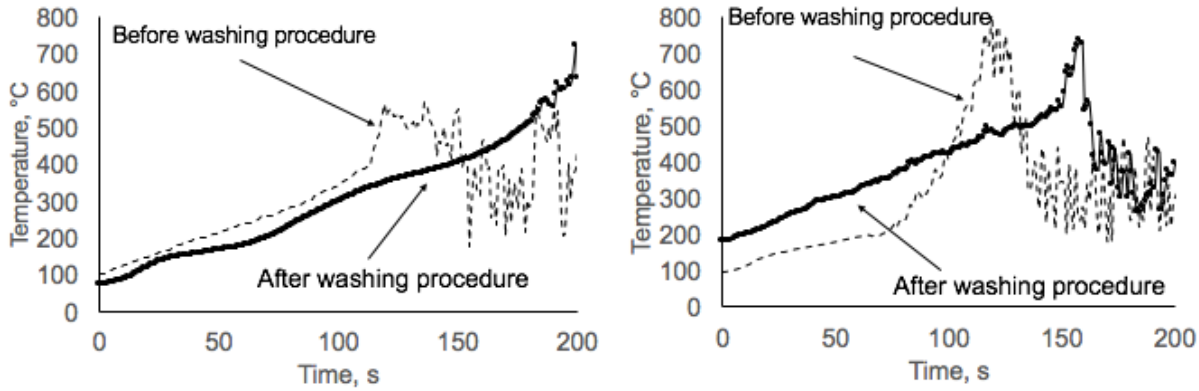

Figure 3. Internal temperature of the pellets before and after the washing procedure during combustion. Left: wood, Right: straw.

Figure 4 shows the emission of Ca*, K* and Na* of the pellets before and after the washing procedure during combustion. The emission intensity of K* was dramatically reduced after applying the washing procedure to the straw samples, whereas the impact in the emission of Ca* and Na* was marginal. In the case of the wood, the washing procedure yielded marginal differences in the emission of Ca*, K* and Na*.

Figure 5 shows the emission of Ca*, K* and Na* of the doped with 0.5%, 2% and 5% of Ca, K and Na during combustion. The combustion period can be identified from the temperature profiles of the raw biomass samples and from the Ca*, K* and Na* emission profiles of the doped biomass, occurring roughly between 50 and 150 s, with variations between samples

with different treatments. Hence, the Ca*, K* and Na* profiles can be correlated to the combustion period.

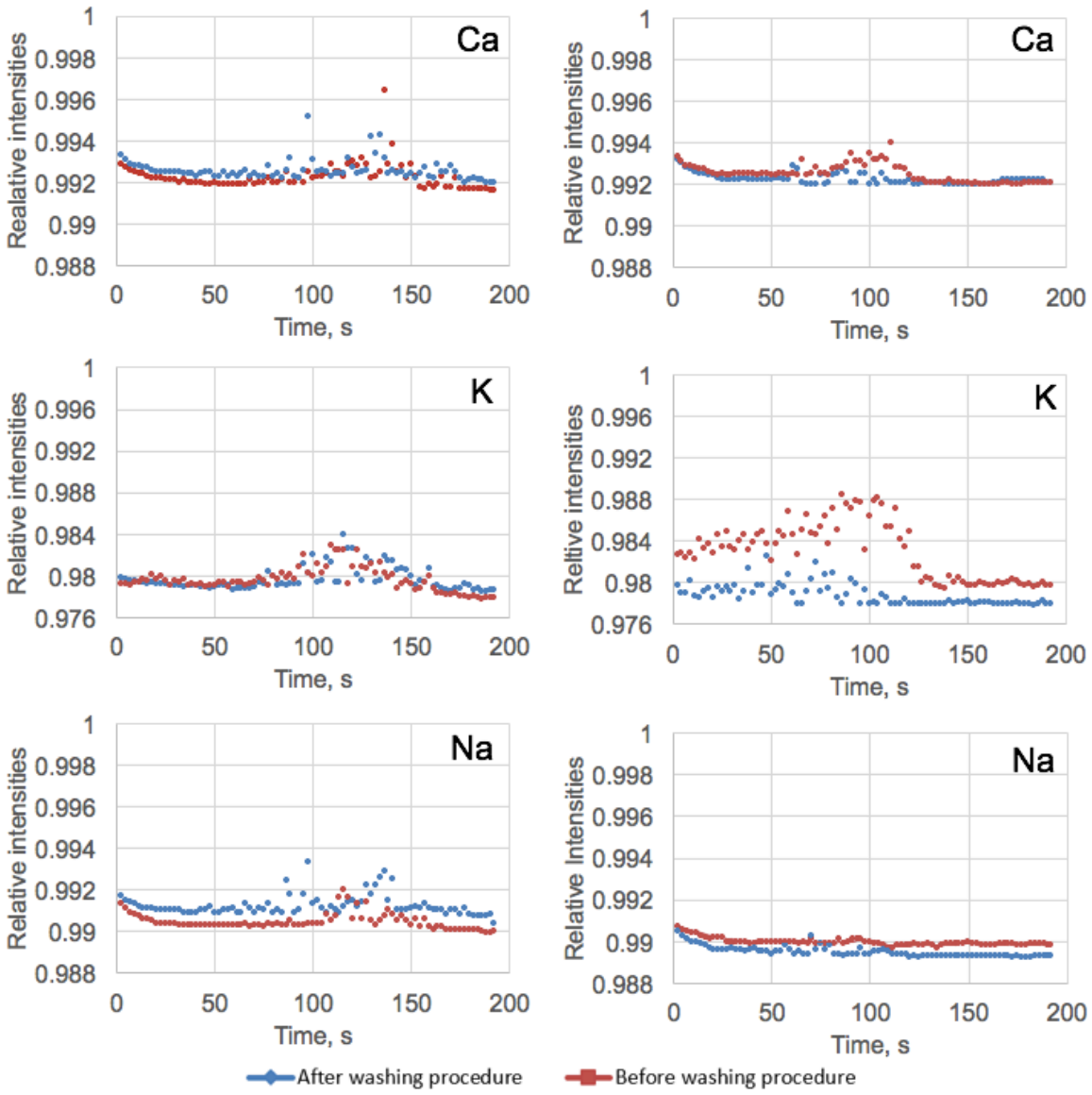

Figure 4. Ca, K* and Na* emissions of the pellets before and after the washing procedure during combustion. Left: wood, Right: straw.*

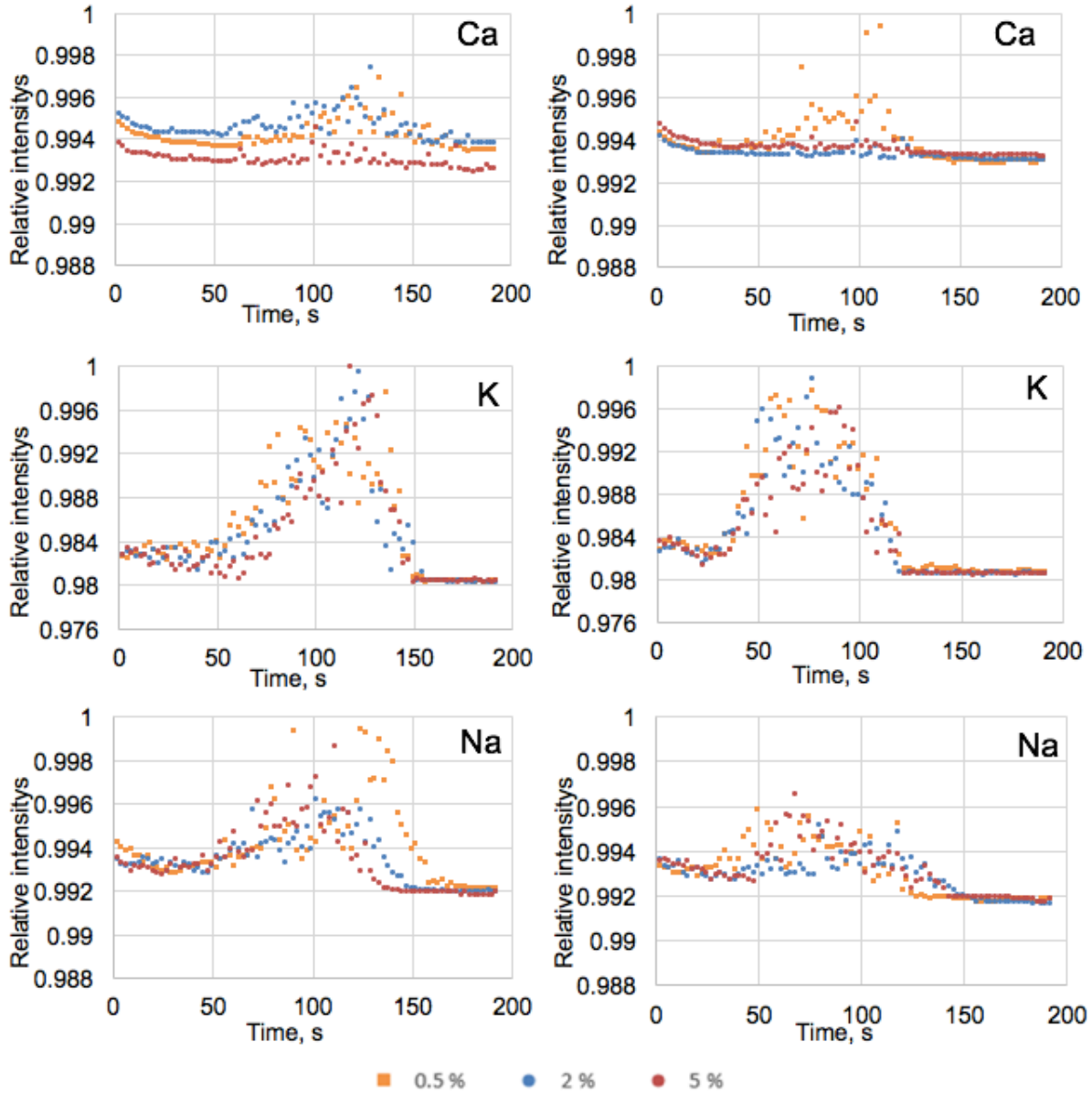

Figure 5. Ca, K* and Na* emissions of the pellets doped with 0.5%, 2% and 5% of Ca, K and Na during combustion. Left: wood, Right: straw.*

4. CONCLUSIONS

The experimental results show that the emission intensity of K* was dramatically reduced after applying the washing procedure to the straw samples, whereas the impact in the emission of Ca* and Na* was marginal. In the case of the wood, the washing procedure yielded marginal differences in the emission of Ca*, K* and Na*. The combustion period can be identified from the temperature profiles of the raw biomass samples and from the Ca*, K* and Na* emission profiles of the doped biomass, occurring roughly between 50 and 150 s, with variations between samples with different treatments. As such, the Ca*, K* and Na* profiles can be correlated to the combustion period.

AKNOWLEDGEMENTS

The authors acknowledge the networking support provided by the COST Action Number CM1404. This work was partially supported by Fundação para a Ciência e Tecnologia (FCT), through IDMEC, under UID/EMS/50022/2013.

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