INFLUENCE OF MOISTURE CONTENT IN WOOD CHIPS ON THE BOILER OPERATION

UTJECAJ SADRŽAJA VLAGE U DRVNOJ SJEČKI NA RAD KOTLA

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Abstract: *Wood chips are often used as a fuel in cogeneration plants. Therefore, the effect of moisture in the wood chips on combustion in one such plant has been analyzed. The heating value of incoming wood with a 40% moisture content was about 10 MJ/kg, and the average ash content was 1.82%. Wood chips with a higher moisture content have a lower heating value, which leads to lower efficiency of the boiler. A decrease of the combustion temperature also occurs as well as an increased amount of CO in the flue gas, but also the lower concentration of NOx compounds.*

Key words: *wood chips, moisture, boiler*

Sažetak: *U kogeneracijskim postrojenjima se često koristi drvna sječka kao gorivo. Zbog toga je analiziran utjecaj vlage u drvnoj sječki na izgaranje u jednom takvom postrojenju. Ogrjevna vrijednost dolaznog drveta s 40% vlažnosti iznosila je oko 10 MJ/kg, a prosječni udio pepela je iznosio 1.82 %. Drvna sječka s višom količinom vlage ima nižu ogrjevnu vrijednost što dovodi do nižeg stupanja efikasnosti kotla. Također, dolazi do pada temperature izgaranja u ložištu te do povećane količine CO u dimnim plinovima, ali i niže kocentracije NOx spojeva.*

Ključne riječi: *drvna sječka, vlaga, izgaranje*

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1. Introduction

The combustion of wood chips has certain specificities concerning fossil fuel combustion (Williams [1], Tarelho et al. [2]). Although the composition of the wood in different forests is very similar, the combustion process can vary (Dzurenda et al. [3]). The moisture content of wood is a significant factor affecting the combustion process. Especially in the case of wood chips, the moisture value varies over a wide range, depending on the length and form of storage. In practice, wood-burning with a moisture content of 10% to 60% is encountered.

The problem with such fuel is to maintain the combustion process within acceptable environmental and economic limits (pollutant emissions within permitted limits and boiler efficiency). This requires the proper construction of the combustion firebox and control of the combustion process (Jirouš [4], Holubčik et al. [5], Dzurenda [6]). Miroslav Rimár et al. [7] investigated the influence of moisture from wood chips on the combustion process. According to experiments, the moisture content affects the air excess, but only to a minimum. As the moisture content is increased from 10% to 60%, the excess air is also increased by only 10% to 15%. ZHANG, X. et al. [8] experimentally investigated and mathematically modeled the combustion of wood in a movable grill boiler.

In many studies, laboratory combustion in a chamber or actual furnaces is adopted to obtain emission factors for different sources. Thus, the influence of combustion parameters was investigated by Chen et al [9], Chomance et al. [10], Grandesso et al. [11], Lu et al. [12] Xie et al. [13]. Lu et al. tested the effect of combustion temperature, fuel moisture, and oxygen content on the emissions of polycyclic aromatic hydrocarbons from crop straw combustion in a laboratory chamber.

The influence of moisture on pollutant emissions and the degree of boiler operation in actual operating conditions of a cogeneration plant is analyzed in this paper. The influence of the moisture content of wood chips on particulate emissions is also significant but is not the subject of research in this paper.

2. Experimental part

The 5 MW power plant is located in Grubišno Polje and was put into operation in early 2019 and it uses wood chips as fuel.

Wood chips are stored outside the power unit of the thermal power plant (Figure 1) and occupy an area of about 800 m^2.

Figure 1. Wood chips warehouse

The warehouse is divided into eight containers for easy sorting and quality monitoring of incoming chips. The entire warehouse holds about 2400 m^3 of wood chips. The transport of wood chips from a warehouse to a daily tank is carried out by dredge having a bucket of 10 m^3 capacity. Two daily tanks together hold about 500 m^3 of wood chips, which is sufficient for continuous operation of the boiler of 12 hours. Each tank is situated on the movable floor and driven by hydraulic cylinders, and the chain conveyor carries chips to the chip dispenser, which is located next to the firebox. It is inserted into the center of the combustion chamber by screws of the chip.

The boiler firebox (Figure 2) is circular in section with conical grate. The height of the firebox falls from the center towards the edges. Chips are first dried on the grate, then the combustion process takes place, and finally, the ash falls from the edge of the grate into the water. Temperatures in the firebox are between 700° C and 900° C.

Figure 2. The firebox in the overhaul phase

2.1. Description of measuring line

Using a measuring line, the quality control of wood chips is carried out for each trailer of incoming wood chips, and, if it is necessary, analyses of wood chips from the container are performed too. Various devices and instruments are used in the process of control and measurement, such as the Apos OPT BA-T, the cutting mill Retsch SM100 wood chipper, press, balance, calorimeter, and furnace. Apos OPT BA-T is the instrument that measures the moisture content of wood chips and calculates the ash percentage and the heating value of the wood chips (Figure 3).

Figure 3. Chip moisture meter (left) and chip cutting mill (right)

The press is used for pressing the sample and the sample drying furnace is used to measure the difference between incoming and dried chips. The calorimeter measures the heating value of the fuel.

2.2. The process of sampling chips and measuring physical quantities

The submitted wood chips must be analyzed to determine the dry mass, moisture, heating value, size, etc. A representative sample of chips is an appropriate quantity of wood chips extracted from the bulk mass with approximately the same properties. The sampling process is carried out following HRN EN ISO 18135: 2017 and HRN EN ISO 14780. A sample of chips is taken from each shipment separately and the code number under which the shipment is received is added.

The sample mass is defined by the standard and depends on the size of the tank or trailer. The sample is further divided into smaller sections and tested (four equal parts). The sample must be well mixed before and after each procedure to obtain representative properties.

2.3. Measurement procedure

After sampling the chips, an analysis according to HRN EN 14774-3: 2010 is performed. The sample is first placed into a device that measures the moisture in wood chips and calculates the ash residue and the heating value. It takes about 8 liters of wood chips for the device to test the unit. Wood chips are then divided into four parts and are weighed on a precision scale (Figure 4.).

Figure 4. The sample labeled on the precision scale

One quarter is placed in a pot that goes into the furnace where it is dried at 104 °C for 24 hours. After drying, the sample is re-weighed and the difference in mass is recorded. The moisture in wood chips is calculated according to expression 1.

$$M = \frac{W_w - W_o}{W_w} * 100 \quad (1)$$

We distinguish between two terms: water content and wood humidity (moisture). Water content (M) is the ratio between water and total wet matter of biomass W_w. Wood moisture (U) is the ratio between water and biomass dry matter (W_o). The moisture is a term more commonly used in industry and can be converted to water content.

$$U = \frac{W_w - W_o}{W_o} * 100 \quad (2)$$

The moisture is an important criterion for the quality of wood chips because it depends on both the heating value and storage requirements. The lower heating value is influenced by the moisture content and the hydrogen content of the fuel. In addition to moisture, the chemical composition, density, and soundness of wood have the greatest influence on the heat value:

$$H_d = \underbrace{H_g \cdot (1-w)}_{1} - \underbrace{r \cdot w}_{2} - \underbrace{r \cdot h \cdot 9{,}1 \cdot (1-w)}_{3} \qquad (3)$$

$$w = m_w/(m_w + m_s) \qquad (4)$$

H_d	MJ/kg	lower heating value of fuel (net calorific value)
H_g	MJ/kg	upper heating value of fuel
r	MJ/kg	heat of evaporation, r = 2,445 MJ/kg at 25 °C
w	kg/kg	moisture content of the fuel
m_w	kg	water mass in fuel
m_s	kg	dry fuel mass
h	kg/kg	mass fraction of hydrogen in kg of dry matter of fuel

The first term in expression (1) is used to reduce the upper heating value to the mass of wet fuel. The second member represents the energy required to evaporate the moisture contained in the fuel, while the third member defines the energy required to evaporate the water produced by the hydrogen combustion.

To determine the heating value of wood chips samples, an adiabatic calorimeter with a calorimetric bomb was used in this case and the heating value was determined by the standard HRN EN 14918: 2010.

Higher moisture content implies that more energy will have to be used for evaporation and there will be an increase in fuel consumption to produce the same amount of energy. Furthermore, with the increase of moisture content, the amount of exhaust gases increases due to incomplete combustion, and the combustion temperature decreases. Also, by the increase of moisture content the emission of gases SO_x, NO_x, HCl, CO, and organic pollutants increase which depends on the quality of combustion. With a higher moisture content, fuel loses its heating value and increases the amount of ash. The amount of ash depends on the quality of wood chips, impurities, moisture content, and the type of wood itself. In extreme cases, ash can cause damage to the boiler furnace grate.

3. Analysis of the obtained measurement results

The moisture measurement in wood chips was carried out over 15 days, during which time the boiler load was constant. Data on the moisture content of wood chips (Figure 5), the amount of wood chips consumed and the heat value of wood chips (Figure 6), and the composition of the exhaust gases were analyzed. During this period, 2016 MWh of electricity was produced. Average daily data were taken.

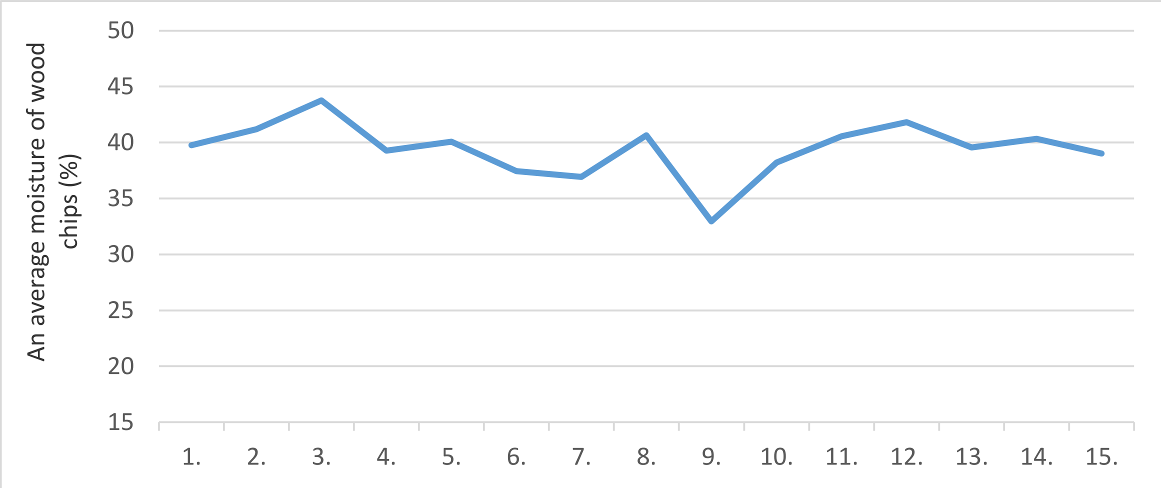


Figure 5. The moisture of wood chips in the analyzed period of 15 days

The average moisture content of wood chips was 39.43% and the average ash content was 1.82%. In addition to moisture measurements, the wood chips' heating value was also measured with a spectrograph meter.

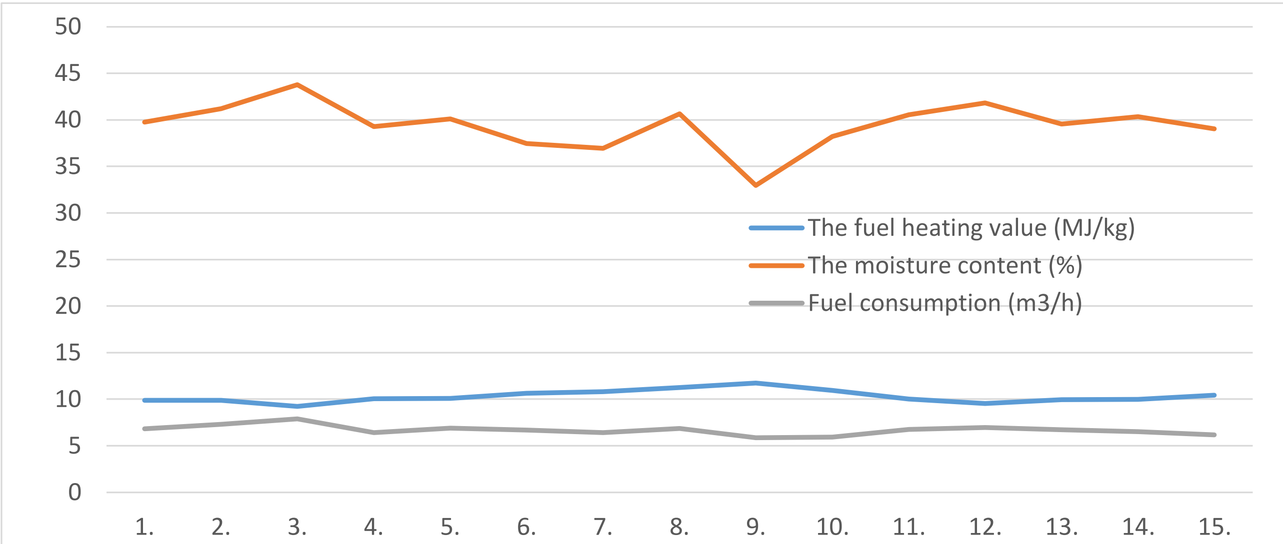


Figure 6..Influence of moisture content in wood chips on
fuel consumption and the heating value

From Figure 6, it can be seen that by increasing the moisture content of wood chips, it's heating value decreases, which causes increased consumption of wood chips to maintain the plant's constant power.

The Regulation on the monitoring of pollutant emissions into the air from stationary sources [14] and [15] defines the gases whose emissions must be monitored. These are carbon monoxide, sulfur oxides, and nitrogen oxides. These gases are accompanied by emissions of chloro and fluoro-hydrogen. In the observed period, the emission limit values of individual gases were not exceeded. The emission of individual gases in the exhaust flue gas is shown in Figure 6. Also, it can be seen that the increase in the moisture content of the fuel increases the share of CO in the flue gases. With the moisture decreasing, the CO content also decreases, but the amount of NOx increases as the combustion temperature in the firebox increases.

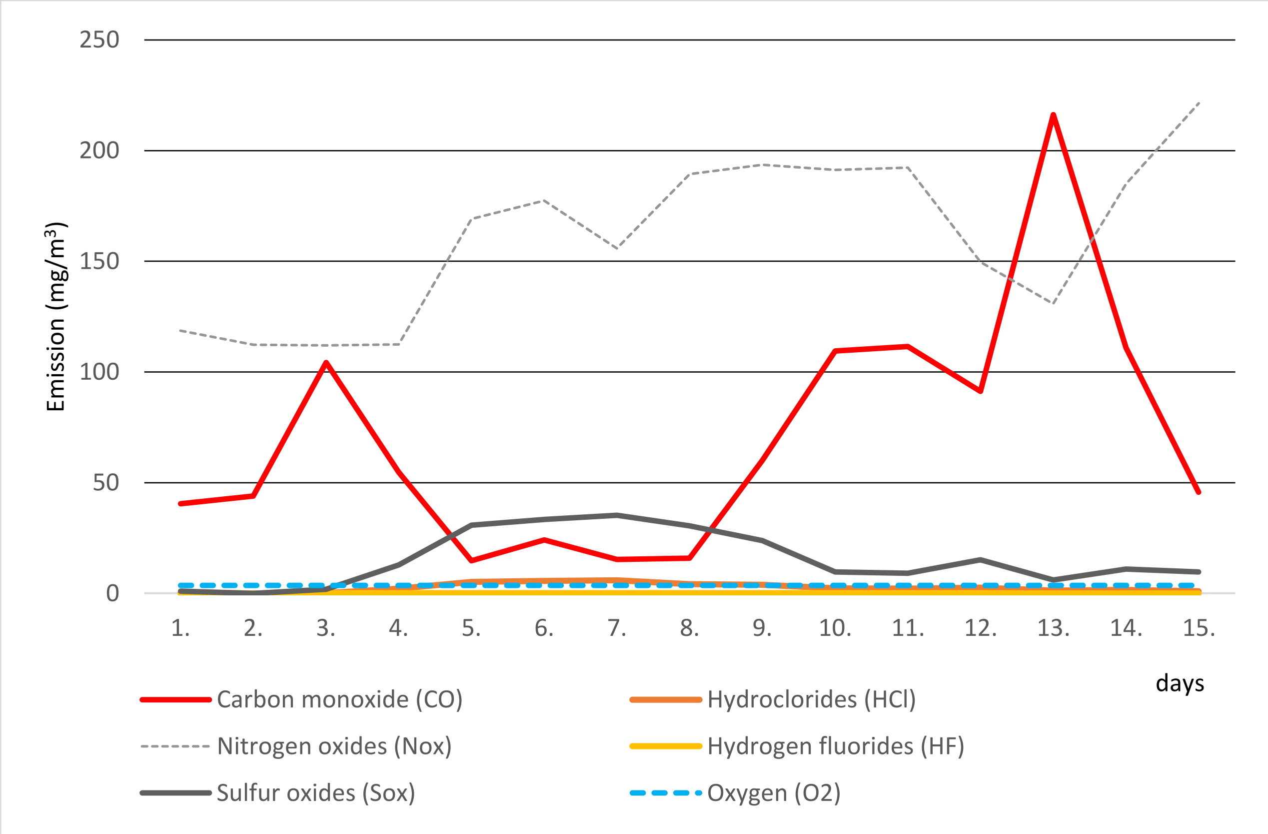


Figure 7. Flue gases analysis

Primary and secondary measures are generally used to reduce nitrogen oxide emissions. The primary measures are aimed at regulating the temperature in the combustion process, ie to lowering the peak temperatures in the flame zone and also above the flame zone. This is achieved by the gradual supply of combustion air (primary and secondary air), but also by the recirculation of flue gases (which, in addition to regulating the temperature in the combustion zones, are also used to dry the wet fuel on a grill). The gradual supply of air to the combustion chamber also regulates the excess air in individual zones, and thus the number of unburned substances (carbon monoxide, fuel particles or soot - unburned carbon).

Secondary measures are focused on flue gas treatment by selective processes catalytic reduction or selective non-catalytic reduction.

The efficiency of the boiler is expressed by analyzing the boiler operation according to expression 5. It is defined as the ratio between the output, output energy of the boiler, and the input energy of the wood chips.

$$\eta = \frac{Boiler\ output\ power}{input\ power\ of\ wood\ chips} * 100 \quad (5)$$

$$\eta = \frac{The\ power\ of\ the\ boiler}{The\ heat\ value \cdot The\ amount\ of\ chips\ consumed} * 100 \quad (6)$$

The calculation from expression 6 gives the degree of boiler efficiency. An average boiler efficiency in the observed period was 92.13%. The dependence of the boiler efficiency on the moisture content of the chips is shown in figure 8.

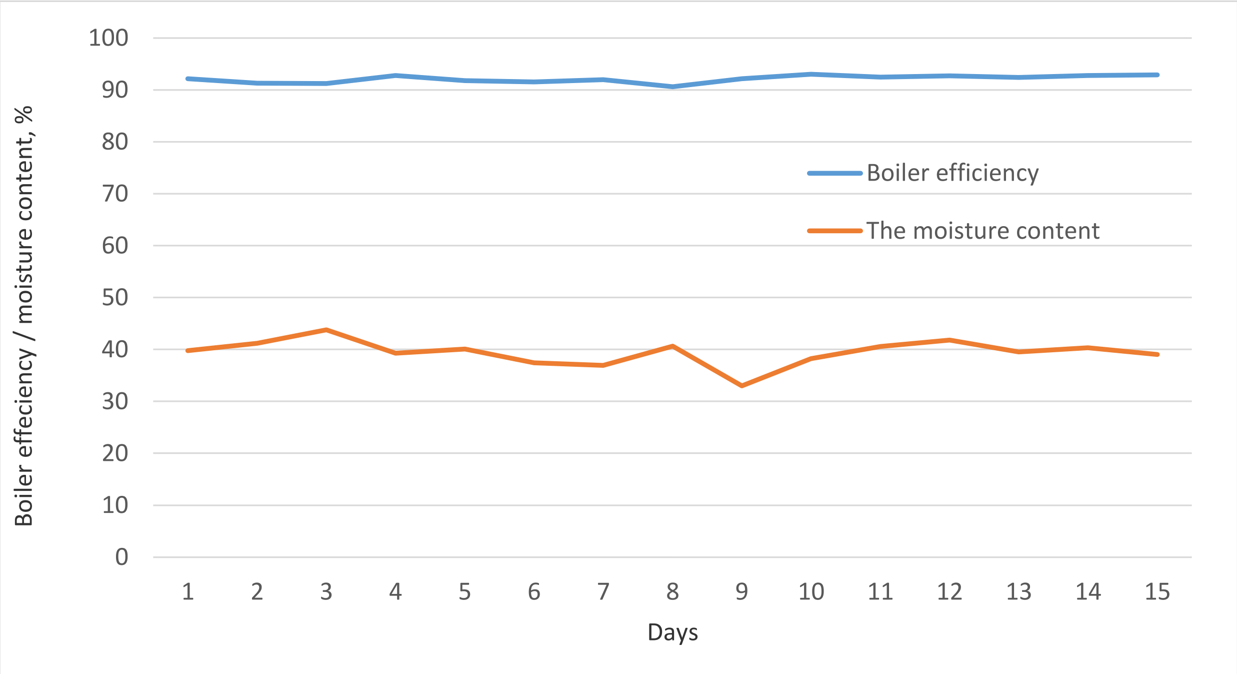


Figure 8. Dependence of boiler efficiency on the moisture in wood chips

According to data obtained for moisture content of 39.77%, the boiler efficiency was 92.18%, and at a moisture content of 43.77%, the boiler efficiency was 91.22%. It can be concluded that higher moisture content of wood chips reduces the efficiency of the boiler because it has to burn more wood chips for the same power. The strength of this study is that results were obtained on the concrete power plant at work.

4. Conclusion

After performed tests and measurements, it is observed that the moisture content has a significant impact on the heating value of wood chips and thus on the operation of a cogeneration plant. When the moisture content in wood chips increases, the efficiency of the boiler decreases. Wood chips with a higher moisture content have a lower heating value, which affects the amount of energy released. Higher moisture content in wood chips causes the wood chips to dry longer in the combustion chamber, leading to a decrease in the combustion temperature.

Due to the higher moisture content, incomplete combustion occurs which affects the composition of the flue gases. Figure 8 shows an increase in the amount of carbon monoxide in the flue gases during periods when wood chips had more moisture content. For chips with greater moisture content, it is important to monitor and optimize the combustion parameters to achieve satisfactory boiler efficiency.

The combustion process, in addition to the moisture content of the combustion chamber, is also affected by the arrangement of the wood chips on the grate, as well as the ratio and amount of primary and secondary air entering the combustion chamber. Different content of moisture in wood chips was most often affected by different excess air, based on theoretical and experiential data. Such actions reduce the impact of moisture on combustion and boiler efficiency.

5. References

[1] Williams, A. (2012). Pollutants from the combustion of solid biomass fuels. *Progress in Energy and Combustion Science*. 38(2): 113–137.

[2] Tarelho, L., Neves, D., Matos, M., A. (2011). Forest biomass waste combustion in a pilot-scale bubbling fluidised bed combustor. *In Biomass Bioenergy*, p. 1511–1523.

[3] Dzurenda, L., Banski, A., Dzurenda, M. 2014. Energetic properties of grenn wood chips from Salix viminalis grown on plantations. *Scientia agriculturae bohemica*, 45(1): 44–49.

[4] Jirouš, F. 1982. Početně analytická kontrola spalování. *Strojírenství* 32(4): 199-203.

[5] Holubčik, M., Jandačka, J., Papučik, S., Pilat, P. 2015. Performance and emission parameters change of small heat source depending on the moisture. *Manufacturing Technology*, 15(5): 826-829.

[6] Dzurenda, L., Banski, A. 2017. Influence of moisture content of combusted wood on the thermal efficiency of a boiler. *Archives of Thermodynamics* 38(1): 63-74., Doi: 10.1515/aoter-2017-0004

[7] Miroslav Rimár – Marcel Fedák – Aleksander Korshunov – Andrii Kulikov – Jana Mižáková: Determination of excess air ratio during combustion of wood chips respect to moisture content, *Acta Facultatis Xylologiae Zvolen*, 58(2): 133−140, 2016 Zvolen, Technická univerzita vo Zvolene Doi: 10.17423/afx.2016.58.2.14

[8] Zhang, X., Chen, Q., Bradford, R., Sharifi, V., Swithenbank, J. 2010. Experimental investigation and mathematical modelling of wood combustion in a moving grate boiler. *In Fuel Process Technol*, p. 1491–1499.

[9] Chen Y, Roden C, Bond T. Characterizing biofuel combustion with patterns of real-time emission data (PaRTED). *Environmental Science & Technology*. 2012;46(11):6110–-6117.

[10] Chomanee J, Tekasakul S, Tekasakul P, Furuuchi M, Otani Y. Effects of moisture content and burning period on concentration of smoke particles and particle-bound polycyclic aromatic hydrocarbons from rubber wood combustion. *Aerosol and Air Quality Research*. 2009;9:404–-411.

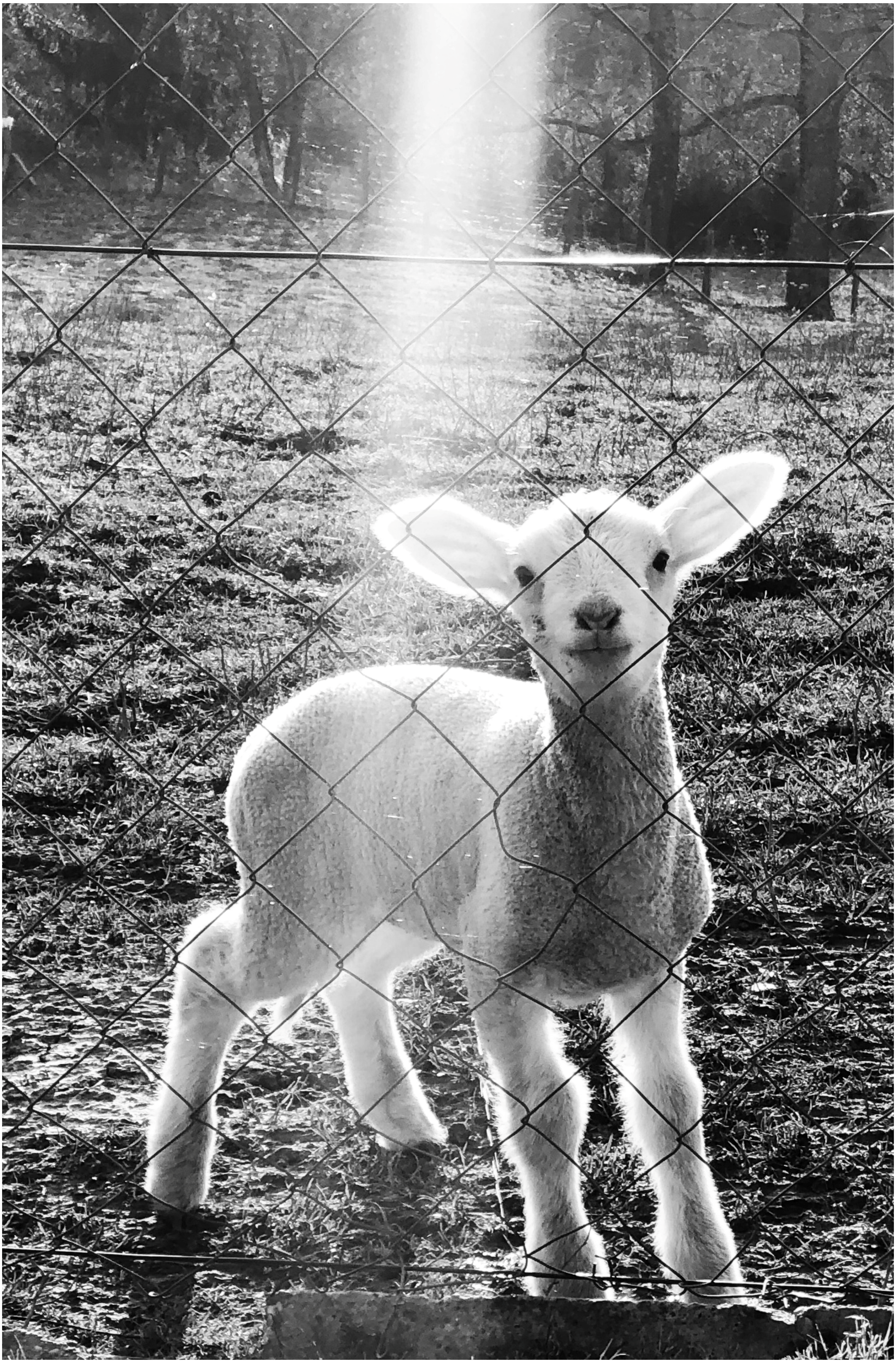
[11] Grandesso E, Gullet B, Touati A, Tabor D. Effect of moisture, charge size, and chlorine concentration on PCDD/F emissions from simulated open burning of forest biomass. *Environmental Science & Technology*. 2011;45(9):3887–-3894.

[12] Lu H, Zhu L, Zhu N. Polycyclic aromatic hydrocarbon emission from straw burning and the influence of combustion parameters. *Atmospheric Environment*. 2009;43(4):978–-983.

[13] Xie J, Yang X, Zhang L, Ding T, Song W, Lin W. Emissions of SO2, NO and N2O in a circulating fluidized bed combustor during co-firing coal and biomass. *Journal of Environmental Sciences-China*. 2007;19(1):109–-116.

[14] Zakon o zaštiti zraka NN br. 130/11, 47/14, 61/17; https://www.zakon.hr/z/269/Zakon-o-za%C5%A1titi-zraka (1. 2. 2020.)

[15] Pravilnik o praćenju emisija onečišćujućih tvari u zrak iz nepokretnih izvora NN br. 129/12, 97/13; http://www.propisi.hr/print.php?id=3951 (1. 2. 2020.)



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