The Comparison of Wood Chips and Cocoa Shells Combustion

Michal Spilacek, Martin Lisy, Marek Balas, Zdenek Skala

***Abstract*—** This article compares the combustion of the different biomass types in a multi-stage combustor. The two biomass specimen are wood chips and cocoa shells. For the testing purposes, the wood chips represents an easily accessible and combustible biomass type with low emissions and the cocoa shells are an unusual specimen that needs to be examined closely. The comparison contains the combustion process, emissions and the operational problems. The monitored emissions are carbon dioxide, carbon monoxide, nitrogen dioxide and particulates, all monitored at the highest achieved efficiency. For the operational problems, the most notable one is the possibility of slugging of the combustion device while combusting the cocoa shells. Co-combustion of the two fuels is not included.

***Keywords*—** cocoa, combustion, biomass, comparison.

I. INTRODUCTION

Energy requirements are ever-changing and in pursuit for lower emissions and emissions of greenhouse gasses it is necessary to seek more and more considerate ways of combustion. That is on the side of more efficient combustion devices [1] and on the side of used fuels [9, 10] as well. For these reasons looking for new fuels has become an important part of combustion research and what was used to be considered waste is now considered an adequate fuel with recognizable potential. One such fuel is a waste from cocoa beans processing – cocoa shells. This fuels seems to be very suitable for combustion and for this reason it is necessary to pay attention to it a found more about its behavior during combustion.

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M. Spilacek is with the Energy Institute, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic (phone: +420 54114 2583; e-mail: spilacek@fme.vutbr.cz).

M. Lisy is with the Energy Institute, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic (e-mail: lisy@fme.vutbr.cz).

M. Balas is with the Energy Institute, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic (e-mail: balas.m@fme.vutbr.cz).

Z. Skala is with the Energy Institute, Brno University of Technology, Technická 2896/2, 616 69 Brno, Czech Republic (e-mail: skala@fme.vutbr.cz).

II. PROPERTIES OF BIOMASS

A. General information

General characteristics of biomass is a very complicated a problematic [2], as biomass fuels from the same species can have different composition depending on location and harvest time. Generally, biomass residues like shells, husks and straw usually contain a higher volume of ashes [3]. Moisture content and higher heating value is not easily predictable, but the volume of ashes, these values should be lower compared to wood chips.

B. Used fuel

In the table below can be seen the results from analysis of three fuel. The cocoa shells, sawdust and woodchips. The ash content of the cocoa shells is by far the highest, resulting in the lowest overall content of combustibles. The moisture content is almost the same as in the wood chips. In a direct contrast with the low content of combustibles is the highest higher heating value of all thee samples.

Tab. 1 Properties of compared fuels

Parameter	Fuel ^{r}		
	Cocoa	Sawdust	Wood chips
Moisture	7.15	9.88	7.35
Ash [mass %]	9.85	0.48	1.55
Combustibles [mass %]	83.00	89.64	91.11
HHV [kJ/kg]	18.08	13.47	17.54
LHV [kJ/kg]	16.85	12.13	16.17
C [mass %]	42.98	47.29	47.09
H [mass %]	4.85	5.05	5.46
N [mass %]	2.64	0.16	0.38
O [mass %]	32.32	37.00	37.97
S [mass %]	0.20	0.15	0.20

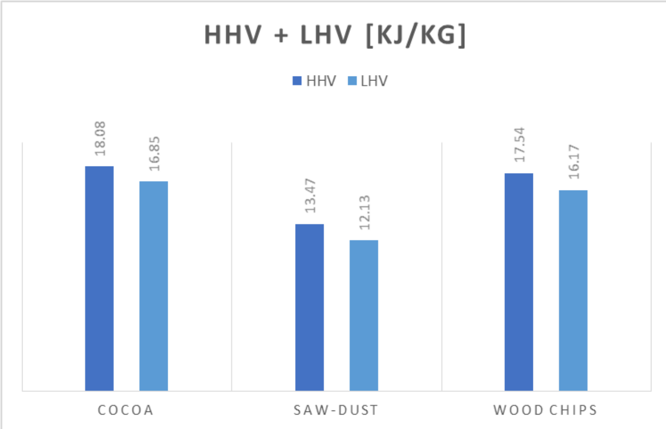

Fig. 1 Comparison of higher heating values and lower heating values

This might be a result of different composition of the respective part of the plant, as all biomass is basically composed of lignin, hemicellulose and cellulose and every part of a plant has different ratio of these three and other components [4]. For the cocoa shells it seem that the constituent with the highest higher heating value is dominant. The same can be said for wood chips. The lower results for sawdust in this case implicate that bark is the main carrier of heating value and cocoa shells should have a similar composition as bark. Because bark has a higher volume of lignin then wood, lignin should be the main cause of the results.

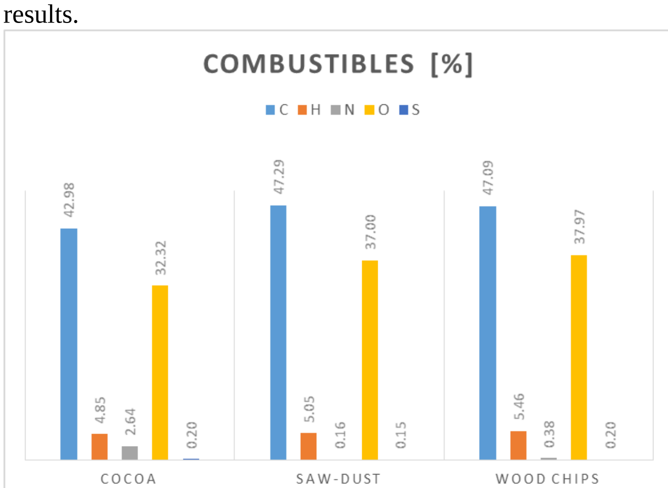

Fig. 2 Comparison of combustibles

Another important characteristic is the content of possible emission producing elements like nitrogen and sulfur. The sulfur content in biomass is generally very low compared to coal and the resulting emission are low [3]. The cocoa shells are no exception. But the content of nitrogen is considerably higher and because nitrogen emissions are highly dependent on combustion temperature, which in the case of biomass are relatively low, the main source of nitrogen emissions is the nitrogen contained in fuel [1]-[6] and this may cause higher than allowed emissions. This will be observed later in this article.

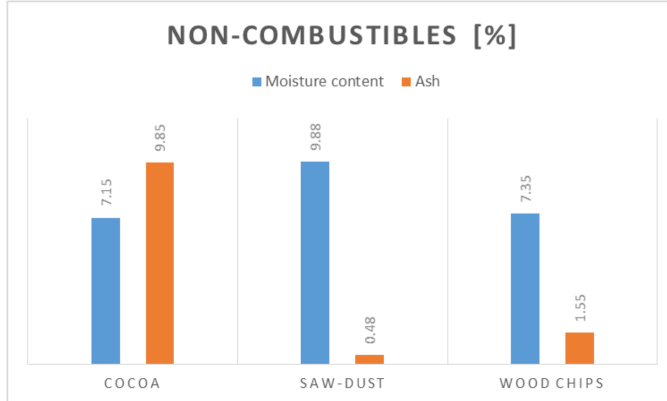

Fig. 3 Comparison of non-combustibles

III. Measurement

A. Experimental device

The experimental device used for combustion of the biomass samples is a modified combustion unit specialized for measurement and extensive control of the combustion process. In consists of these main parts: Gasification chamber, Water heater, fuel feeder, air preheater and measurement and regulation unit.

1) Gasification chamber

The Gasification chamber is meant for better control of the combustion process by a better resolution of the main biomass combustion stages (drying, pyrolysis, combustion of volatiles, and combustion of char), mainly the pyrolysis. To observe the process, three thermocouples are placed evenly over the length of the chamber and one pressure gauge is measuring the underpressure in the chamber. To achieve better control over the combustion of volatiles and char, combustion air is distributed in three parts: primary, secondary and tertiary air. A better view of the chamber is provided by Fig. 4.

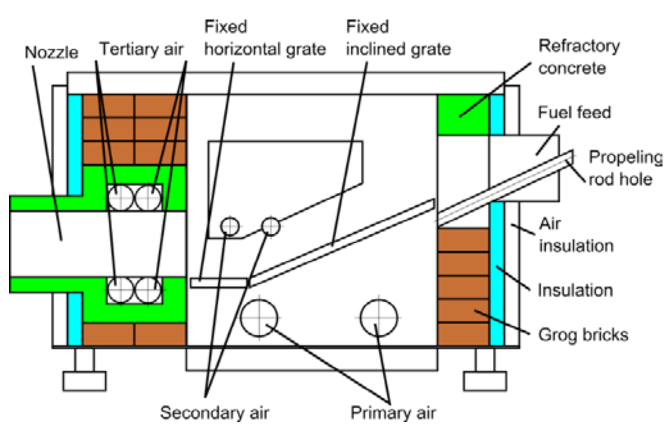

Fig. 4 Gasification chamber

2) Water heater

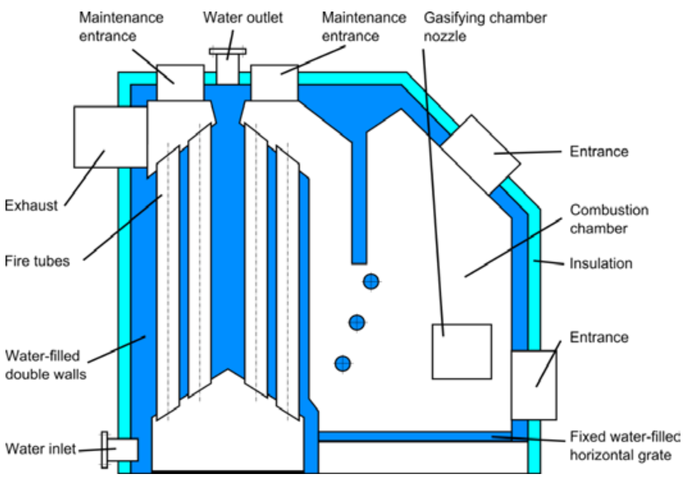

Fig. 5 Water heater

After the combustion products leave the gasification chamber they enter the water heater. Here they are cooled down and transfer their heat in water. The water heater is a standard grate combustion unit for wood, but in our case no wood is placed inside and all heat is brought by the combustion products from the gasification chamber. The nominal power output is 110 kW. For our purposes it is equipped with three thermocouples. A cross-section of the water heater is shown in Fig. 5.

3) Other parts

The other parts. For more information about the device, its specifications, other parts (fuel feeder, air preheater, water circuit and measurement and regulation) and function see [7].

B. Readings

1) Combustion

Even with the characteristics of moisture content and higher heating value similar to the woodchips, combustion of cocoa shells yielded high temperatures "easily". These were about 300 °C higher then when combusting wood chips (Fig. 6 and Fig. 7). The mentioned figures are showing temperature and power output progress over time.

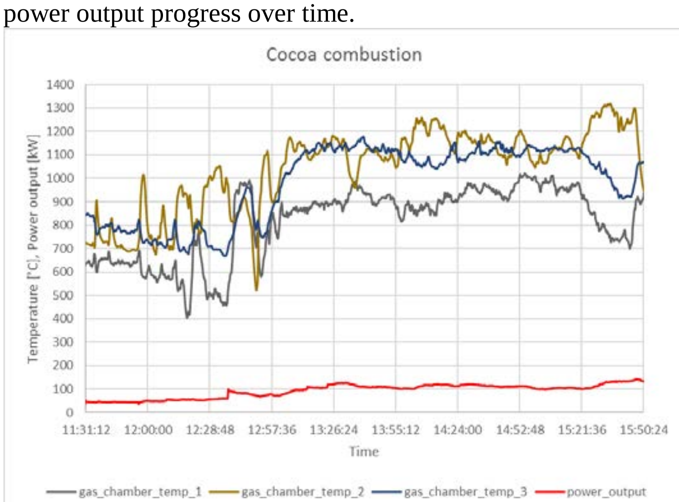

Fig. 6 Cocoa combustion

While woodchips were able to reach nominal output of 110 kW without reaching melting point of ashes that usually are over 900 °C [8]. In our case the temperas are almost reaching 1000 °C and no signs of melting were observed.

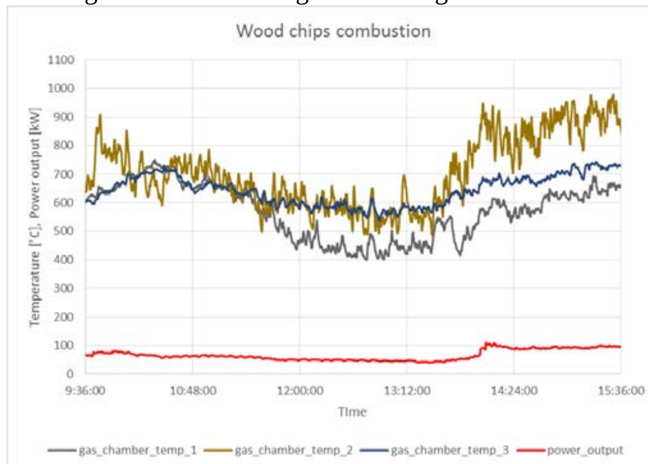

Fig. 7: Wood chips combustion

Cocoa shells, on the other hand, reached the temperature of 1200 °C and for some time over 1300 °C and the melting point of ashes was reached, creating an uniform and thick cover of hard, almost glass-like porous material on the grate of the gasification chamber. That cover lately caused a considerable damage on said grate that needed a welding repair to continue working.

2) Emissions

Having in mind the high temperatures and content of nitrogen in the fuel, the emissions from the combustion must be observed more closely. The results can be seen in Fig. 8. They show results from a 30 minutes long measurement after reaching a stable combustion that is characterized by the oxygen concentration around 11 % in the flue gas. The peaks in CO emissions are most probably caused by avalanching of the fuel and the consequent incomplete combustion. The levels of SO_2 are very small, but the level of NO are mostly between 1000 – 1400 mg/m^3. That can be considered a fairly high number.

3) Ash coating

Another observed issue, that may cause problems, is a creation of a grey coating on heat exchanging surfaces made from ash. Analysis of the ash has shown that it is made from a very fine particles. Some of these particles have a size smaller than 1 μm. The particle sizes are in Fig. 9. Such fine coating will reduce heat flux and the efficiency of the device. Also, such fouled device will require a more often cleaning, reducing the effective working time.

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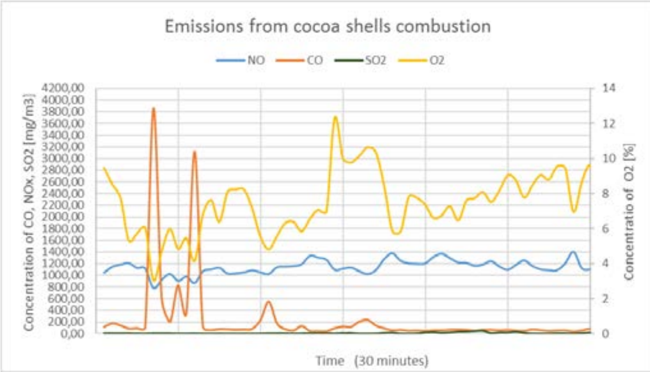

Fig. 8 Emissions from cocoa shells combustion

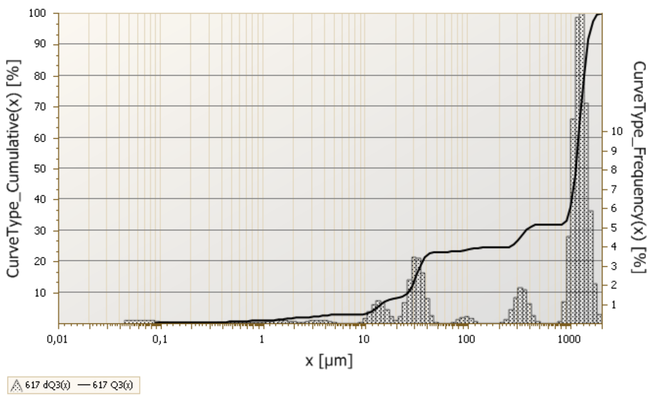

Fig. 9 Fine ash coating

IV. Conclusion

After a brief testing of cocoa it seem that this fuel may be considered a suitable biomass for combustion with characteristics comparable with the ones of wood chips. But it has some disadvantages that must be taken in consideration while combustion. First there are "easily" achievable temperatures that are above the melting point of aches causing slugging. Second, fly ash is composed of very fine particles that create a coating on heat exchanging surfaces. Such coating may result in lowered efficiency of the device and a more frequent need for cleaning. Lastly, higher yield of nitrogen oxides may render the fuel unsuitable for bigger combustion units without a precision emission control system.

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