The Use of Maize Stalks for Energy Purposes and Emissions Measurement during their Combustion

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Abstract
The objective of the work was a monitoring of possibilities of maize cortical harvesting by combine harvesters and its subsequent use for energy purposes during combustion. We monitored the combustion of packages with the moisture of 18% and 38% and the effect of moisture on the content of gas emissions of CO_2, NO, NO_2 as well as the percentage of residual O_2 in the flue gas after combustion. All values of monitored emission limits were in current normative limits defined in Collection of Laws no. 356/2010.

Keywords: emission limits, maize cortical, maize cortical combustion, maize cortical harvesting, renewable energy.

1. Introduction

Maize is one of the agricultural crops, which have wide use from the view of phytomass production and is considered the third millennium crop. Why? Because human and animal nutrition is impossible without maize. Alcohol, oil and biogas, also plastics, thermal insulation and other materials can be produced from maize, even electric energy by means of biogas cogeneration. Maize is primarily an economically profitable crop [1, 2].
Considering combustion, characteristics of biomass are important; main indicators of quality are values of water content in biofuel, chemical composition of combustible fuel, content of volatile matter, biofuel heat value [3].
Maize stalks have a heat value of 14.4 $MJ.kg^{-1}$ at moisture level of 10%, at the volumetric weight of 100 $kg.m^{-3}$ in packages. Treatment of biomass is required for its use improvement. Biomass material pressing at very high pressure is a working process, which we refer to as compaction in the final phase [4].

Traditional multi-operational maize straw harvesting is performed in the following steps, which are defined by primary method of grain maize harvesting, it means what type of machine was used to harvest maize crop [5].
Grain harvest is performed by conventional combine harvesters with adapter for grain maize harvesting with crushing maize stalks under combine-harvester. After that, maize straw crushing is performed. This is followed by maize straw and stubble grinding by means of hammer and knife mulching machine [6].

2. Materials and methods

The objective of the work was a monitoring of possibilities of maize cortical harvesting by combine harvesters and its subsequent use for energy purposes during combustion.
Maize cortical was cultivated on farm in Rastislavice on the area of 34.62 hectare (fig. 4, 5). The pressing of maize cortical was performed by pressing machine KUHN LSD 1270 for large-volume, square packages (fig. 1). Packages have been removed from the territory and stored.

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Figure 1. Pressing machine KUHN LSB 1270 for large-volume square packages

We chose incineration of Menert-Therm in Šaľa, which provides heating of several residential buildings, for packages from maize cortical combustion. Compressed packages of maize cortical with dimensions of 220 x 120 x 90 cm, with a weight of 400 kg, with a moisture content of 18% and 38% (fig. 2) were used as combustion material.

Figure 2. Package of maize cortical inserted into the dosing device of incinerator

Emissions measurement from the combustion of phytomass was performed by measuring device TESTO 350 M/XL, which is used by the Department of machines and production systems. Modular system TESTO 350 M/XL is composed of three main parts (fig. 3). This device is calibrated for accurate emissions measurement, while the evaluations of the measured values are based on emission limits defined by the Clean Air Act no. 137/10 and by the Decree Ministry of Environment of the Slovak Republic no. 356/2010.

From a variety of values, which could be measured by TESTO 350 M/XL, for analysis, we chose O_2, CO, CO_2, NO, NO_2 gases, as well as control values: flue gas temperature, qA, lambda and efficiency.

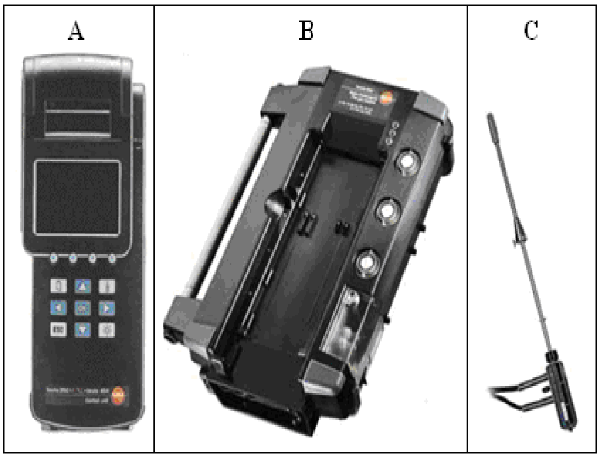

Figure 3. Modular system TESTO 350 M/XL for the analysis of flue gases: A – control unit, B – analyzer box, C – sampling probe

3. Results and discussion

Considering opportunities of PD Rastislavice and incineration of Menert-Therm in Šaľa, we proceeded with maize cortical utilization as a source of energy for heating of residential buildings.

Monitored values of biological yield of maize phytomass

Measuring data of biological yield of grains and stalks after harvesting on monitored parcel are graphically presented and processed by system environment of GIS (fig. 4, 5).

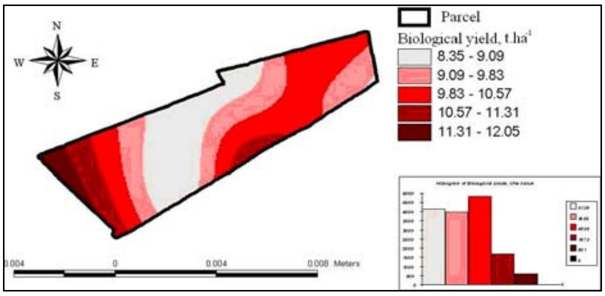

Figure 4. Evaluation of variability of biological yield to monitored parcel ($t.ha^{-1}$)

Based on measured and graphically evaluated values we can conclude that the phytomass yield is very variable. Biological yield of grains on monitored parcel ranged from 8.36 to 12.05 $t.ha^{-1}$ and yield of maize material was in the range of 11.34 to 15.8 $t.ha^{-1}$.

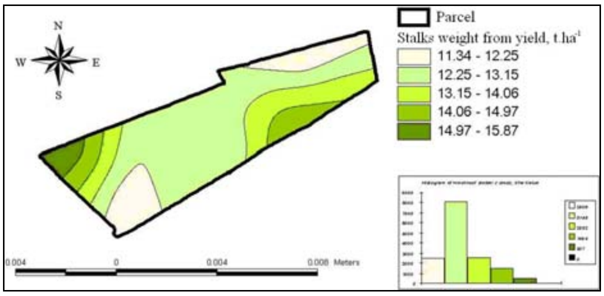

Figure 5. Evaluation of variability of stalks weight from yield after harvest (t.ha^{-1})

Comparison of measured characteristics parameters of combustion and emissions at different moisture level of maize cortical.

Results of experimental measurements are shown in figure 6. and table 1. Some values are presented in internationally recognized units of ppm (parts per million). Results of the average values of experimentally monitored emissions are more favorable for combustion of maize cortical at moisture of 18% than at 38% moisture.

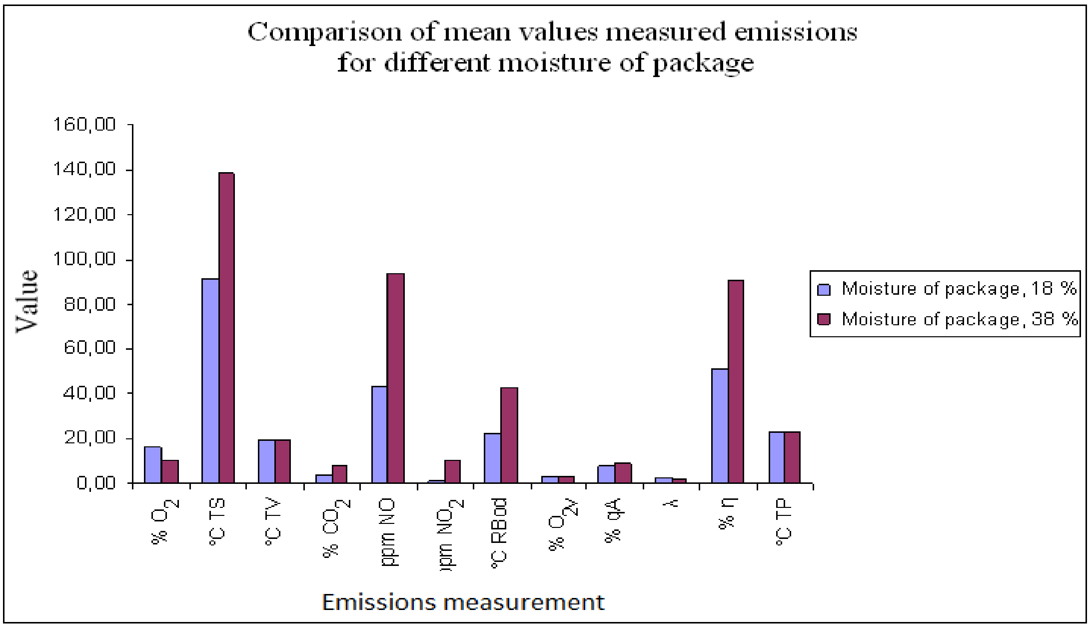

Figure 6. The average values of the measured characteristics of burning and emissions from the combustion of packages of maize cortical

Table 1. Main statistical parameters of selected measured data

Statistical parameter	O_2 (%)	CO_2 (%)	NO (ppm)	NO_2 (ppm)
Mean value	15.92	3.57	43.57	0.99
Error of the mean value	0.19	0,15	1.45	0.08
Median	18.94	1.51	28.00	0.50
Standard deviation	5.51	4.17	41.60	2.34
Dispersion	30.39	17.40	1730.48	5.49
Taperness	- 1.15	- 1.18	- 0.93	235.18
Obliquing	- 0.75	0.72	0.69	13.70
Range	15.63	11.46	146.00	43.80
Minimal value	5.37	0.00	0.00	0.00
Maximal value	21.00	11.46	146.00	43.80
Addition	13053.78	2929.69	35726.00	811.80
Amount, pc	820.00	820.00	820.00	820.00
Coefficient of variation	0.38	0.29	2.85	0.16

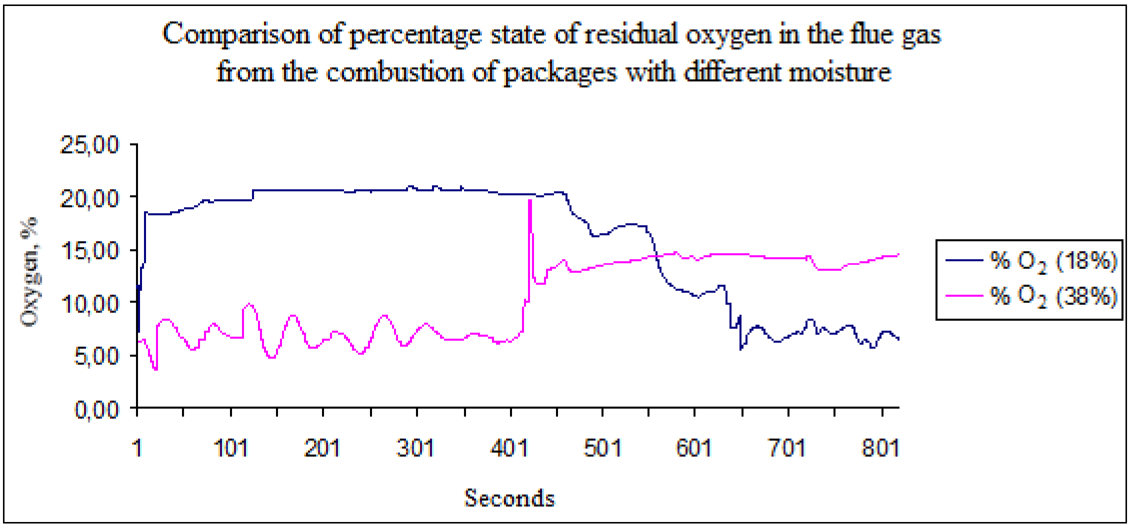

Figure 7. Comparison of percentage state of residual oxygen in the flue gases from the combustion of packages with different moisture content depending on the time of combustion

Measurement of percentage values of residual oxygen in the flue gases from the combustion of maize cortical

Measured and evaluated results are shown graphically in figure 7.

Based on measured values, we can allege that time-scale percentage state of oxygen in the flue gas has an average value of 15.12% with a maximum value of 21% and a minimum value of 5.37%. As presented in graphical form, at the start of combustion (inserting the tapered part of the package to the boiler) oxygen conditions are very different but after stabilization of combustion oxygen conditions are stable in the range from 10 to 15%.

Measurement of CO_2 content in the flue gases from the combustion of maize cortical

Process of CO_2 content in the timeframe is shown in figure 8. Based on measurement results, we detected very different values of CO_2 emissions when inserting the package into the boiler and subsequent stabilization of values in the range of 0.6 to 11.4 ppm.

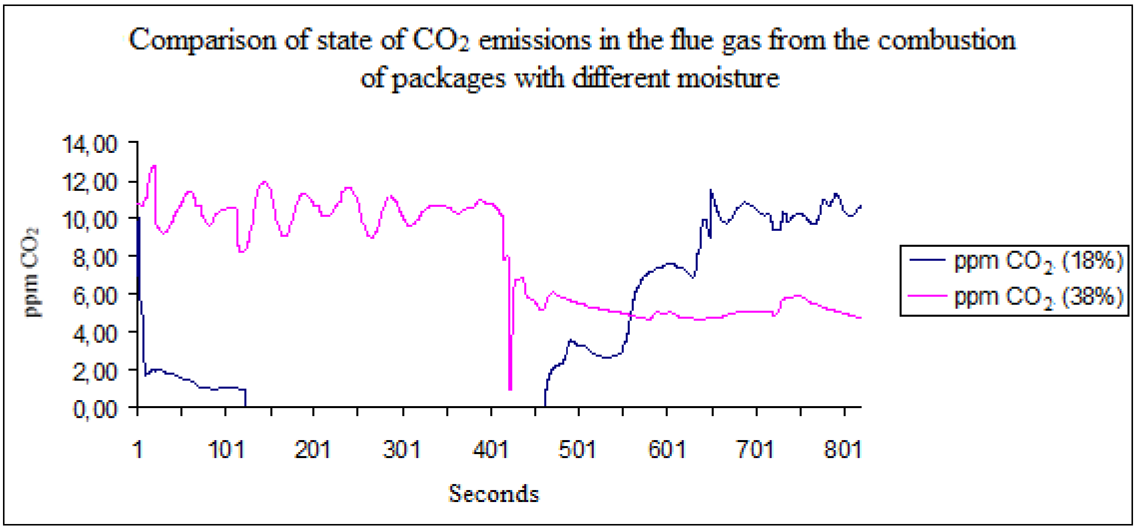

Figure 8. Comparison of state of CO_2 emissions in the flue gases from the combustion of packages with different moisture content depending on the time of combustion

Measurement of NO content in the flue gases from the combustion of maize cortical

Process of measured values of NO emissions is shown in figure 9. State of NO emission from the combustion of cortical is very variable at the start of combustion, but after stabilization of combustion, values are within acceptable numbers around 43.56 ppm.

Measurement of NO_2 content in the flue gases from the combustion of maize cortical

The results of measurements of NO_2 emissions by modular system TESTO 350 M/XL are shown in figure 10. State of NO_2 emissions from the combustion throughout the time horizon is circulating around the value of 0.99 ppm, but combustion of dumpy cortical after the chamber closing caused an increase of value to 43.8 ppm.

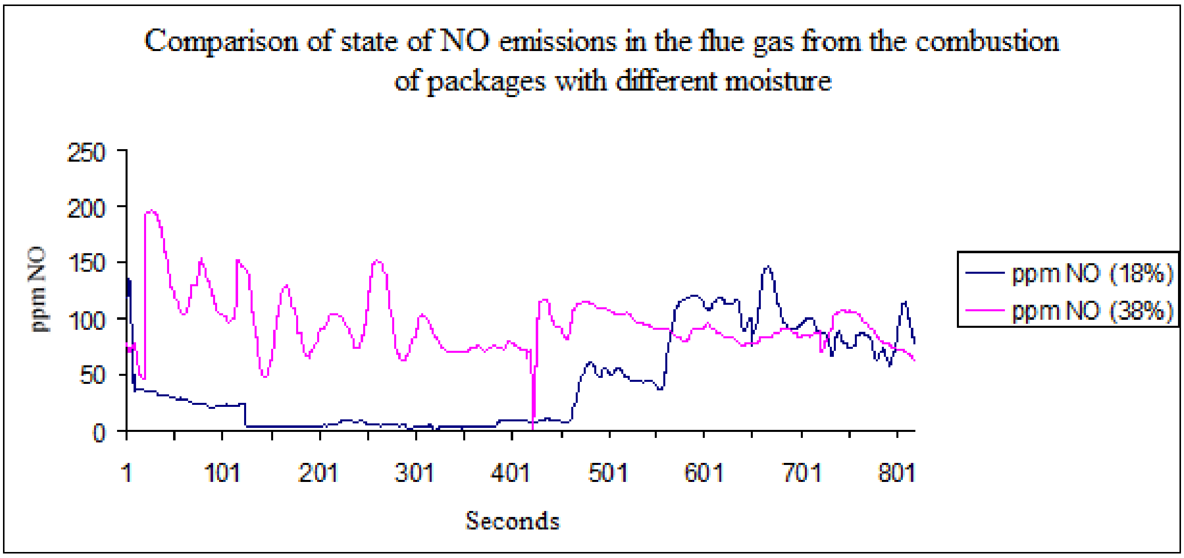

Figure 9. Comparison of state of NO emissions in the flue gases from the combustion of packages with different moisture content depending on the time of combustion

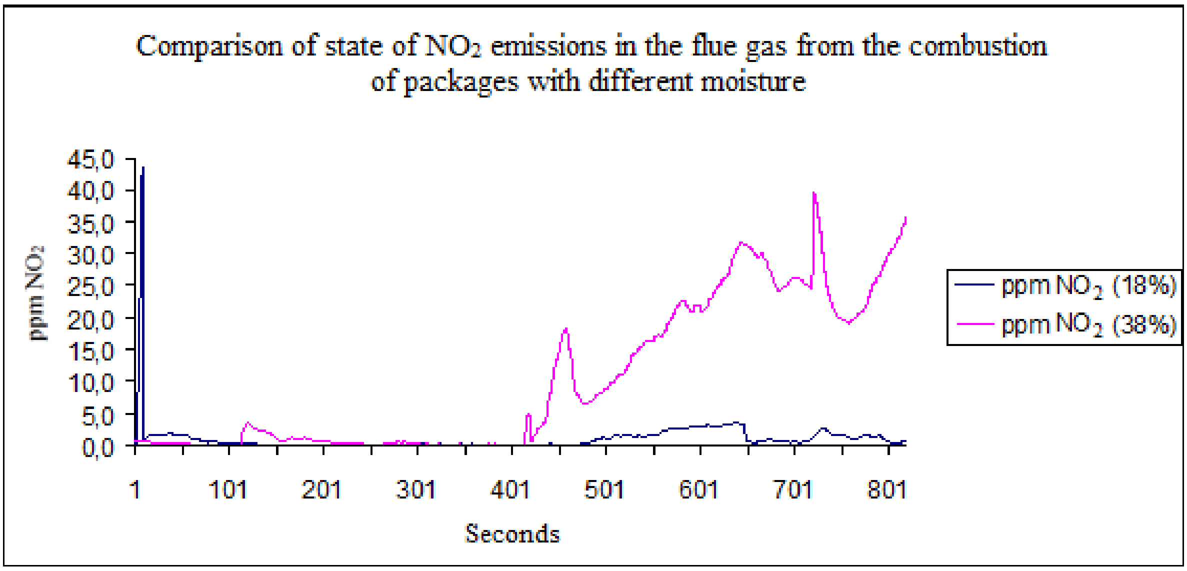

Figure 10. Comparison of state of NO_2 emissions in the flue gases from the combustion of packages with different moisture content depending on the time of combustion

4. Conclusions

Based on measured experimental results and their assessment it can be concluded that the use of maize cortical for energy purposes during combustion is real and, considering climate gas emissions, measured values are within emissions limits defined in Collection of Laws no. 356/2010, page 2955, article 1.9. Stationary equipment for combustion of fuel with a total nominal power of 0.3 MW to 50 MW. All emissions limits are in accordance to monitored standards for CO_2, NO, NO_2, but on the other hand it should be noted that the more favorable results are based on combustion of cortical with moisture of 18% than at 38%. The issue of maize cortical harvesting considering machinery, technological and economical viewpoint within the Slovak republic is poorly understood, therefore, these issues will be the subject of further research at the Department of machines and production systems.

Acknowledgements

The research leading to these results has received funding from the European Community under project no 26220220180: Building Research Centre „AgroBioTech".

References

1. Angelovič, M., Účinky technologických a technických faktorov na kvalitu produktu pri zbere a pozberovom spracovaní kukurice na zrno. In: Habilitačná práca, Nitra VES SPU, 2004, 206 p.
2. Jobbágy, J., Simoník, J., Klimkiewicz, M., The influence of fertigation on agro-physical properties of arable plants. In: Selected problems of soil tillage systems and operations, Warsaw, 2010, pp. 99-107, ISBN 978-83-928876-6-9
3. Maga, J., Piszczalka, J., Biomasa ako zdroj obnoviteľnej energie, Nitra SPU, 2006, 104 p., ISBN 80-8069-679-9
4. Pepich, Š., Ekonomické dopady využívania biomasy v energetike poľnohospodárskeho podniku. In: Agrobioenergia, 2006, pp. 9-10, ISSN 1336–9660.
5. Jandačka, J., Mikulík, M., Ekologické aspekty spaľovania biomasy a fosílnych palív, Žilina Vydavateľstvo GEORG, 2008, 116 p. ISBN 978-80-969161-7-7
6. Birrell, S., Biomass harvesting, transportation and logistics, Iowa state university. 2006, www.bioeconomyconference.org/images/Birrell,%20Stuart.pdf

Elektronická zbierka zákonov, 2010. Home page address: http://www.zbierka.sk