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DETERMINATION OF MECHANICAL AND ENERGETIC PROPERTIES OF REED CANARY GRASS PELLETS PRODUCTION

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Abstract

Authors of the article are evaluating characteristics of half-operational experimental agro-pellets production. The problems of production and use of agro-pellets is the current issue. It's a way to apply part of the agricultural production in the market. It is also an opportunity to replace part of the fossil fuels and increase the share of renewables. But the use of phytomass is bringing many problems. First, it is important that the manufactured products will be succeeded on the raw materials market. Agro-pellets therefore must have characteristics that support their competitiveness and allow their classification. The advantage comes if the agro-pellets properties are comparable with traditional fuels and their combustion is possible in standard boilers. This objective can be achieved in several ways. The production of mixed fuels is one from the possible ways. Phytomass is pressed into pellet form in a mixture with other raw materials, usually based on powder coal or wood. The advantage of mixed fuels production is the ability to influence the final properties according to market demands and requirements of legislation. The research activity results, which are given in the text, were aimed at the possibility of Reed Canary Grass applying as part of a mixed fuel in various concentrations. The pellets are based on Reed Canary Grass and wooden biomass in the form of saw-dust. Addition of sawdust has negative influence on the presser productivity, but has a positive impact on mechanical and burning qualities of final products. Mechanical durability values of pellets were increased by 4.8 and 3.0% with the sawdust addition. The specific weight of pellets was increased even by 31.9%. Hand in hand with the raising amount of sawdust in pellets, the decline of CO emissions in exhaust gas was proven.

Keywords: agropellets, Phalaris arundinacea, bioenergy, biofuels, briquettes, pellets, renewable energy

INTRODUCTION

The interest in various kinds of solid biofuels based on energy crops has achieved rising tendency in the last decade Magó *et al.* (2009), Vojtela *et al.* (2013) and Bácskai and Tóvári, (2016), Madár *et al.* (2018). The field of solid biofuels is represented mainly by pellets and briquettes based on wooden biomass and fytomass nowadays. The pressed biofuels from wooden biomass can be taken into account as a standard energy source in the meantime. However this cannot be claimed for sure in the case of solid biofuels based on the fytomass. In the field of agro-pellets production, for instance, there is a significant potential for growing, especially by target-planted or residual agricultural products. The issue of burning dealt with Prochnow *et al.* (2009). From the heating values and prices point of view these fuels are about Jevič and Hutla (2010) and Kuncová (2004). balancing in the range which is close to soft coal-lignite The competitive ability of such kind solutions is depending mainly on the current granting-subsidy – policy for this specific branch nowadays. Abrahám and Kovářová (2006) Because of this reason, it is necessary to pay special attention to specific production parameters of particular final products. The energetic utilisation of Reed Canary Grass and its economical evaluation was made by Platace (2013). Detailed research on this issue together with all exploitation possibilities, containing even agro-technical measures, was described by Strašil (2012) and Souček *et al.* (2003). The understanding how spring-harvested reed canary-grass briquettes with various chemical compositions with respect to ash content influence the formation of emissions during combustion in a 180 kW burner was described by Paulrud and Nilsson (2001). The results showed low mean values for carbon monoxide (< 42 mg/MJ, except one experiment) and particles in the flue gas (< 150 mg/m^3) (no purification of flue gas). Emissions of nitrogen oxides were (< 110 mg/MJ). For example CO and NO_x emission parameter values of briquettes incineration consisting of energy sorrel, reed canary grass and brown coal mixture are slightly lower as compared with energy sorrel briquettes incineration Koutný *et al.* (2007).

The Costs in different stages of production chain of reed canary grass are between 25 and 28 € MWh^{-1} Lindh *et al.* (2009).

The volume weight of reed canary grass was determined 600–840 kg/m^3, destruction force 10–35 N/mm and range of pressing pressure 14–21 MPa Plíštil *et al.* (2005).

Within the research project realisation, the half-operational, based on Reed Canary Grass, agro-pellets production has taken place. These agro-pellets produced from Reed Canary Grass in different proportions with wooden biomass were put to the test for mechanical and burning qualities assignment. The aim of the research was to determine the parameters of the production of mixed fuels based on reed canary grass and their properties.

MATERIALS AND METHODS

Reed Canary Grass obtained from the large straw bales was shredded at the cutting shredder RS 650 (Kovo Novák, Czech republic) with the installed sieve containing 8 mm diameter holes. Batches of raw material were inserted manually. The important parameters of the device can be found in the Tab. I.

Pressing mixtures of Reed Canary Grass with wooden biomass were prepared by homogenization from the crushed material. The wooden biomass was added in the form of dry sawdust. Mixtures were made in following proportions:

- 100 % Reed Canary Grass
- Reed Canary Grass + sawdust 3 : 1
- Reed Canary Grass + sawdust 1 : 1
- 100 % sawdust

Homogenized mixtures were used for pellets production on the MGL 200 (Kovo Novák, Czech republic) production line, which is equipped with horizontal-matrix granulation press. Basic operating parameters of the whole line provided by manufacturer are shown in the Tab. II; the scheme is on the Fig. 1.

Following parameters were measured during all operations on above mentioned machines:

- Electric energy consumption
- Operating time
- Total weight of final products

The values of these indicators per unit of production were calculated based on obtained data (Specific electricity consumption, efficiency).

Monitored and calculated were: Total weight of produced pellets, electricity consumption, one-hour capacity of the line, specific electricity consumption, specific water consumption, combustion heat and heating value of pellets, solids and water content of pellets.

Following parameters were laboratory-set on final products:

- Specific weight
- Mechanical durability
- Water content
- Heating value
- Combustion residue content

Content of CO a NO_x emissions during combustion was set by burning test in the boiler with automatic fuel-feeding.

Emissions were measured by fume duct with Testo 350 xl device (Germany) and counted over to referential oxygen content of 10%.

Statistical analysis

A statistical analysis was carried out using the software package "Statistica 12.0" (StatSoft Inc.,Tulsa, Oklahoma, USA). Analysis of variance was conducted and the results were compared using the Tukey's multiple range test (α = 0.05).

RESULTS AND DISCUSSION

The specific electricity consumption 0.12 kWh/kg at the efficiency of 58.66 kg/h was noticed during crushing in the shredder. Combustion heat of the crushed material was 17.92 MJ/kg.

The surveillance of responsible person is necessary during the whole production process in regular intervals for assurance of the smooth material flow through the whole line. The specific electricity consumption data of particular pressing mixtures are in the Tab. III.

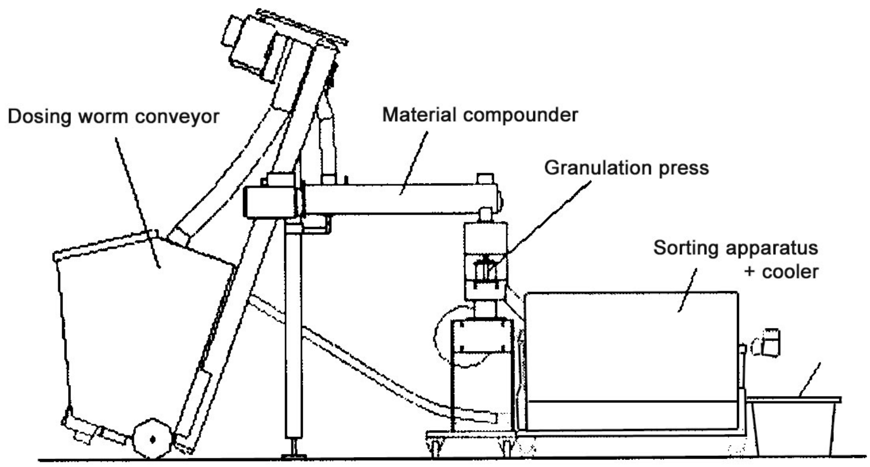
The water content was comparable within all made pellet samples. It varied between 3.8 and 7.9%. The specific weight and mechanical

I: *The technical parameters of shredder Kovo Novák RS 650*

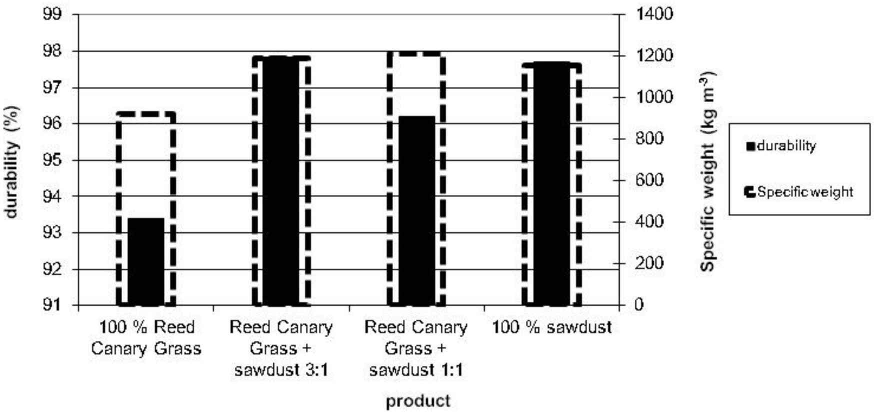
Input	5.50 kW
Connection	400V/25A
Wight	185 kg
Dosing hole diameter	76 mm
Shredding performance (4 mm sieve)e	300–600 kg/h

II: *The technical parameters of pellet line MGL 200 parameters*

Input	8.85–10.85 kW
Weight	430 kg
Connection	400V/25A kat. C–D
Performance: wooden pellets	Approx. 50 –100 kg/h
Performace: bio pellets	Approx. 50–150 kg/h



1: *The scheme of pellet line MGL 200.*



2: *Specific weight and mechanical durability of produced pellets*

III: *Specific electricity consumption and production line efficiency during pressing*

Pressed material	Specific electricity consumption (kWh/kg)	Efficiency (kg/h)	Water content (%)
Reed Canary Grass 100%	0.148 ± 0.012[a]	48.47 ± 1.236[d]	3.83 ± 0.451[b]
Reed Canary Grass + sawdust 3 : 1	0.185 ± 0.009[b]	39.47 ± 1.203[c]	4.84 ± 0.518[a]
Reed Canary Grass + sawdust 1 : 1	0.251 ± 0.020[c]	23.01 ± 1.427[b]	4.70 ± 0.493[a]
sawdust 100%	0.327 ± 0.018[d]	22.05 ± 1.334[a]	7.92 ± 0.455[c]

Legend: Data are expressed as means ± standard deviation, different letters in the same columns represent significant difference ($P < 0.05$).

durability values of produced pellets can be seen on the Fig. 2.

Significant difference in specific electricity consumption and production line efficiency was detected by analysing of working operations within solid biofuels from crushed Reed Canary Grass and sawdust production. The highest efficiency as well as the lowest specific electric energy consumption was proven during pressing of pellets based on the Reed Canary Grass only. On the other hand, the worst results were reached in the case of single sawdust. It is possible to say that Reed Canary Grass addition to the pressing mixture had a positive impact on all followed-up pressing parameters, as can be seen in the Tab. III.

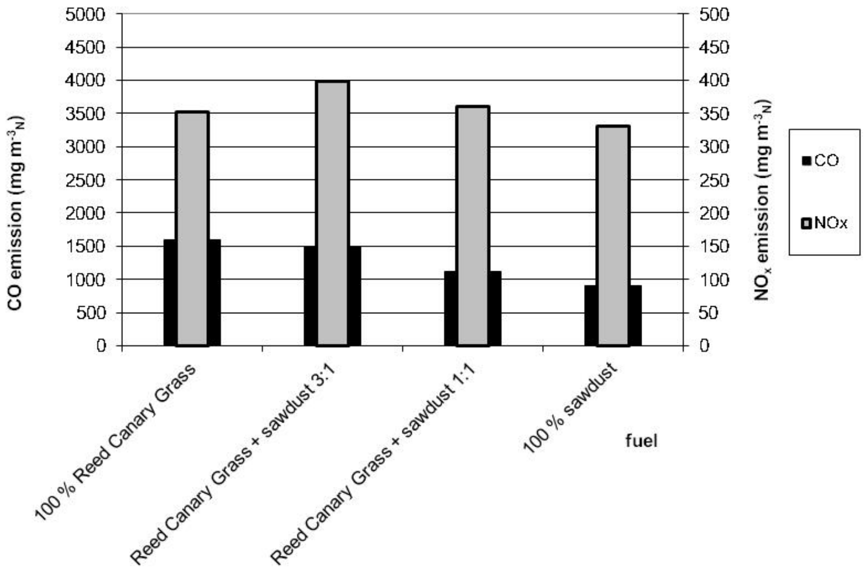
The worst mechanical qualities of 100% Reed Canary Grass pellets were proven, as could be seen on the Fig. 2 (specific weight 920 kg/m^3, shattering 93.38%). The best mechanical durability of pellets made from the mixture of Reed Canary Grass and sawdust in the ratio of 1:3 was noticed (specific weight 1,192 kg/m^3, shattering 97.83%). The highest specific weight was reached by the mixture of Reed Canary Grass and sawdust in the ratio of 1:1 (specific weight 1,213 kg/m^3, shattering 96.20%).

From the emissions production point of view (Fig. 3) the highest amount of CO in 100% Reed Canary Grass pellets was noticed (1,604 mg/m^3_N). On the opposite rather low CO emissions were noted in the case of sawdust (907 mg/m^3_N) and the mixture 1:1 (1,119 mg/m^3_N). Emissions of NOx were oscillating between 331 mg/m^3_N (sawdust 100%) and 398 mg/m^3_N (Reed Canary Grass + sawdust 3:1). It is possible to claim that from the extreme levels point of view all samples containing sawdust are meeting the requirements of the statutory order no. 352/2002 for small appliances. Results of CO a NO_x emission measurements during burning tests are counted over to referential oxygen content of 10%.

Most of the authors are evaluating the Reed Canary Grass from agronomical and economical point of view in the literature. Abrham (2006) and Platace (2012). Strašil (2012) is presenting the yield at the level of 6.8–8.3 t/ha. Platace, and Adamovics (2012) are declaring combustion heat values by 17.48–18.55 MJ/kg.

These data are corresponding with combustion heat values of tested samples (17.92 MJ/kg). It means the heating value 15.81 MJ/kg at the water content of 5%, so the energy profit from 107 to 131 MJ/ha.

Emission values are comparable with Paulrud and Nilsson (2001). Depending on the composition of the briquettes as stated Koutný *et al.* (2007).



3: *CO and NO_x emissions counted over to referential oxygen content of 10%.*

CONCLUSIONS

It is possible to improve the mechanical and burning qualities of final biofuels by the addition of wooden biomass in the herbage-based agro-pellets production. The increase of mechanical durability by 4.8 and 3.0% was reached with the mixture of shredded Reed Canary Grass and sawdust (mixing ratio 3:1 a 1:1) in the specific case of experimental half-operational agro-pellets production. The specific weight values of pellets were improved by 29.6 and 31.9%. The statistically significant positive impact of sawdust addition on the CO emissions reduction was proven. On the other hand, there was no statistically significant decrease in NOx emissions.

Production of pellets from plant raw materials and waste materials from agriculture is a promising technology. The resulting product may not be used only for combustion. An alternative way is to use pelleted raw materials for pyrolysis with biochair or for animal bedding.

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