Emission from energy herbs combustion

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ABSTRACT: The energy herb and waste agricultural biomass create important potential of fossil fuels replacement for heating. At present is being used straw, other energy crops are energy sorrel, reed canary grass, knotweed and miscanthus. At biomass combustion are monitored CO and NO_x emissions. For five types of fuels were measured the emission parameters during their combustion in boiler for straw of output 1 MW. The CO emissions are very different for individual fuels. The highest values were achieved for energy sorrel combustion.

Keywords: energy crops; emissions; combustion; heating; boiler room; biomass; energy sorrel

In the framework of EU the Czech Republic has committed to provide 6% of primary energy consumption from renewable energy sources. For replacement of the fossil fuels exist currently some possibilities. It regards mainly phytomass utilization either as a waste or purposefully grown for energy. The classical waste raw material from agriculture is cereal straw, mainly wheat straw. For its utilization as fuel were constructed and built the central heating plants which are at present extended in some European countries, e.g. in Denmark. It results, among others, from share of energy straw on total biofuel potential of individual countries and from effort of specific country for biomass energy utilization. The straw importance for energy utilization in old EU countries is presented in Fig. 1 (Thrän 2001).

Denmark is also example of country, where straw energy potential is being used in maximum amount. In 2001 this utilization was about 94%. There exist to this date 9 power plants for straw of total electric output over 100 MW. In the Czech Republic are in operation some central heating sources for straw combustion. Heat from these plants is delivered to villages or cities.

During the straw combustion are generated emissions of CO and NO_x with concentration permitted till level limited by the legal regulations. For systems with heat output about 1 MW (typical device for straw combustion in form of pressed bales) is valid the CO limit in flue gases 650 mg/m^3 and NO_x limit 650 mg/m^3 (Decree of Government 2002). These values are valid for referential content of oxygen 11%. Similar German regulation TA Luft determines the limit values for combustion device with heating output higher than 1 MW, i.e. 250 mg/m^3 of CO and 350 mg/m^3 of NO_x (Hering 2004).

The example of two German central heating sources in Schölen and Jena (Hering 2001) is presented, where the measured values of emissions for combustion of different straw types and of whole plants did not exceed the mentioned limits. Similarly presents Rathbauer (2001) the short-time measurements of emissions at six Austrian heating plants for straw. The measured values are presented in Table 1 (converted from ppm to mg/m^3 for oxygen referential content 11%).

The same author presents the measured emissions from special combustion device for straw, developed by straw boilers manufacturer. The values for different fuels are presented in Table 2.

Because straw is partially a scarce commodity, the program of energy herbs growing is in development. From wide range of these crops, of which some are subsidized by sum of 2,000 CZK/ha/year in framework of the principles for financial support allocation for establishing and maintenance of herbs growth for energy utilization grown on arable land. That support is an initiative of the Subsidy and Guarantee Rural and Forestry Fund in cooperation with the Ministry of Agriculture of the Czech Republic

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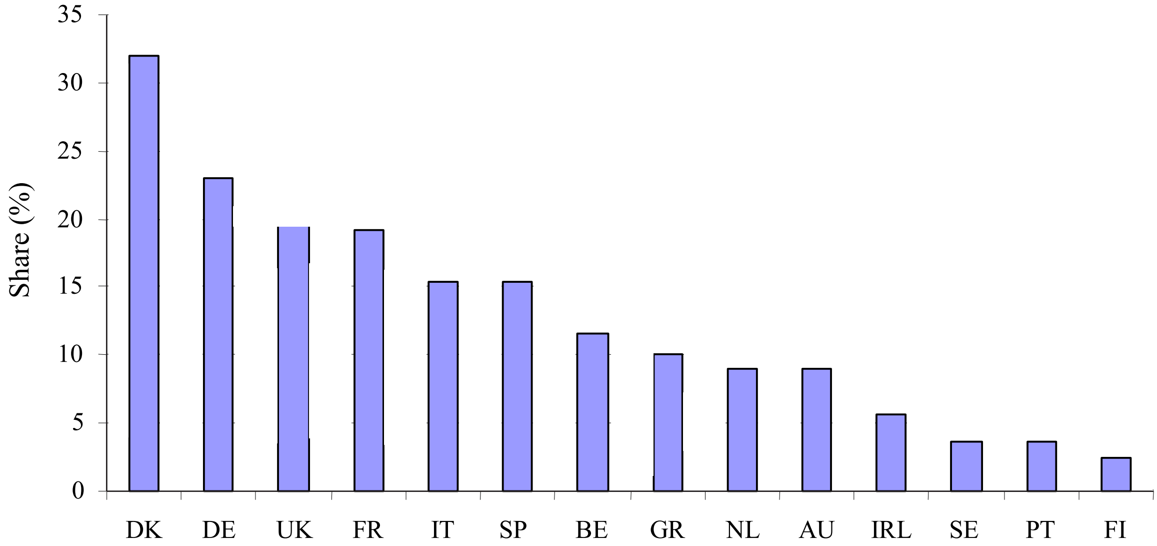

Fig. 1. Share of energy utilized straw on total useable energy potential of biomass in some EU countries

(Petříková 2004). On basis of this iniciative has begun the utilization of energy sorrel in practice (Usťak 2004). Prospective also could be growing of the reed canary grass (*Phalaris arundinacea*). Its seed stock is available on market. Disputable is growing of miscanthus (*Miscanthus sinensis*) due to high costs resulting from the seed stock price. This crop is grown in restricted amount in Germany and Austria. Other very perspective crop is knotweed (*Reynoutria sachalinensis*). Nevertheless for that crop the growing technology is not available particularly as regards the growth establishing. The both mentioned crops are not listed among the energy materials supported by the Ministry of Agriculture of the Czech Republic.

It is necessary to verify the effect of that substitution on operational properties of whole heating system within the replacement of straw as a fuel by some other above mentioned energy herb. The complications can occur at mechanical fuel supply to be boiler, i.e. from the bale separation until the fuel supply into the combustion chamber. Further, the emission values in combustion products could change considerably and the change is possible also in the ash properties and thus in its handling and liquidation.

Objective

To find out the CO and NO_x emissions during combustion of some types of biofuel produced from energy herbs in boiler of medium heating output.

MATERIAL AND METHODS

The combustion device used for some types of biofuel is represented by the boiler TFS 1000 (manufacturer Tractant Fabri, Cologne) of nominal heating output 1.0 MW (Fig. 2).

That boiler is designed for combustion of cereal straw supplied into the boiler room in form of big

Table 1. Emission values of some Austrian central heating sources for straw (Rathbauer 2001)

Plant	1	2	3	4	5	6
CO (mg/m^3)	302	1,081	1,051	2,898	4,001	3,758
NO_x (mg/m^3)	239	187	188	285	202	230

Table 2. Emission values for different biofuels measured at special combustion device of Austrian manufacturer (Rathbauer 2001). Value given in mg/m^3, 11% O_2

Fuel	Limit	Straw I	Straw II	Triticale		Reed
				without fertilization	with fertilization	
CO	250	94	92	39	82	80
NO_x	300	164	218	198	206	125

Fig. 2. Boiler TFS 1000 for straw combustion (in the right). In the left side of the picture is reserve heating source Paromat simplex for Biodiesel combustion

square bales. The bales are delivered from the chain conveyer into the separator and from this device the material is fed by the screw conveyers into the heating chamber.

The boiler is designed as partially gasifying with relatively massive heat lining and vertical heat-exchanging surface with additional heat exchanger for air heating. The combustion device consists of the operational container and after-combustion chamber. The operational container consists of the lined shaft fitted by the upper lid, fuel supply on the sidewall and removal device on the bottom. The wall between the container and after-combustion chamber is fitted with ports for passing through of the burning gasified straw parts into the after-combustion chamber. The chamber is of negative pressure type and consists of two lined shafts. It has the cooled ceiling and to the space of the first shaft is supplied secondary combustion air. The combustion product discharge from the second shaft underneath into the heat pipes of the vertical heat-pipe boiler. The operational container and after-combustion chamber create a compact unit. The second unit consists of the vertical heat-pipe boiler. The boiler is double-draught with input and output chamber for combustion products on the boiler bottom and turning chamber on the top. To the combustion products output from the boiler is attached the air pipe heater. The air ventilator provides supply of the heated air into the secondary air nozzles. Through the combustion products the ventilator regulates vacuum in the combustion device. On the bottom of the operational container is built-in the cooled rake grate for ash removal into the sweeping screw. This sweeping screw, formerly in form of spring was replaced by the helix during the testing operation, sweeps out the ash into the container outside of the boiler room.

The boiler serves for heating of the village Velký Karlov, situated in the Southern-East part of the district Znojmo. The village representation decided for central heating of the village by biomass in 1999 on basis of balance sheet on the construction financing – utilization of own sources, subsidy of the State En-

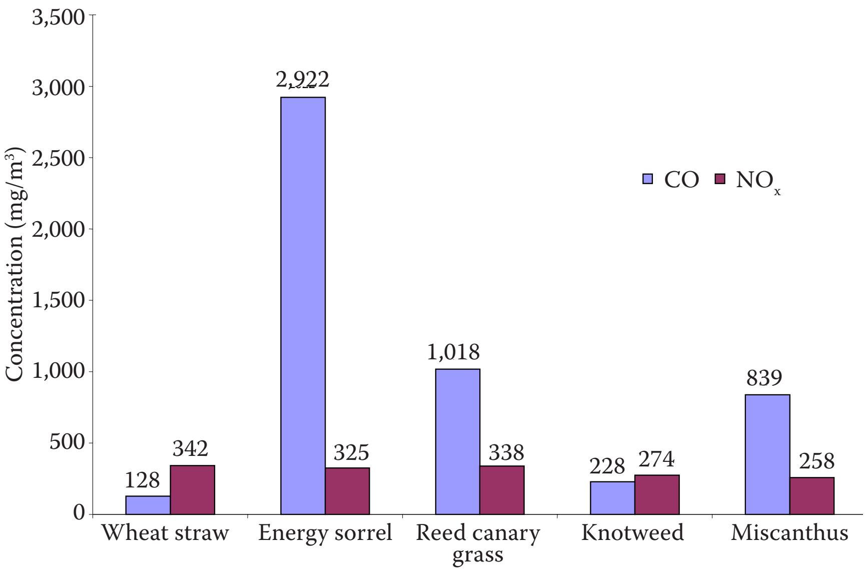

Fig. 3. Average values of CO and NO_x emissions values in combustion products of boiler TFS 1000 for various fuels, at oxygen referential content 11%

Table 3. Results of referential measuring of selected gaseous emission and heat-technical parameters of the combustion device, TFS 1000 in the central heat source of village Velký Karlov in 2003

Type of culm crops biofuels	Thermal output (kW)	O_2 (% v/v)	CO_2 (% v/v)	CO			NO_x			HCl			Combustion products temperature (°C)	Air surplus λ	Heat-therm. combustion efficiency (%)
				(ppm)	(mg/m_N^3)	O_{2V} = 11% (mg/m_N^3)	(ppm)	(mg/m_N^3)	O_{2V} = 11% (mg/m_N^3)	(ppm)	(mg/m_N^3)	O_{2V} = 11% (mg/m_N^3)			
Limit values valid in the CR	–	–	–	–	–	650	–	–	650	–	–	–	–	for 11% O_2 = 2.1	–
Wheat straw	550	12.7	9.4	86	106	128	138	283	342	152	252	388	92	2.54	93.7
Feeding sorrel	820	12.8	8.1	1,924	2,406	2,922	128	267	325	120	213	259	111	2.57	90.3
Reed canary grass	640	13.7	7.2	597	746	1,018	119	248	338	109	198	270	110	2.88	90.4
Knotweed	733	10.1	10.5	199	249	228	144	300	274	139	238	219	116	1.93	93.3
Miscanthus	760	14.5	6.3	434	543	839	80	167	258	78	133	206	114	3.25	88.8

vironmental Fund of the Czech Republic, Czech Energy Agency and foreign subsidy. The village comprises 124 family houses and 8 public facilities (municipality, nursery school, cultural-social hall, 2 shopping centres, restaurant, housing facility and sport club cabins). The heat is distributed to customers by the insulated pipe system of Danish company LØGSTØR RØR in channel-free seating. The distribution system length within the village is 1,915 m, branch pipes to the facilities are produced from the insulated flexible pipeline (netting polyethylene) in total length of 1,223 m. In each facility is installed transfer station with board exchanger LPM. The eventual withdrawal maximum values and short time shut down are leveled by the hot water supply from the accumulation tanks with capacity of 80 m^3.

The test operation was started in the second half of 2001. In 2003 was carried-out the verification of selected energy crop suitability in the heat main source. Besides wheat straw in form of the high-pressure bales were successively tested: energy sorrel (*Rumex tianschanicus* × *Rumex patientia*), reed canary grass (*Phalaris arundinacea*), knotweed (*Reynoutria sachalinensis*) and miscanthus so called "Elephant grass" (*Miscanthus sinensis*).

The emission parameters in the combustion products were measured by the apparatus MADUR GA60. The principle of that device is utilization of the electro-chemical converters for oxygen (O_2), carbon mono-oxide (CO), sulphur di-oxide (SO_2) and hydrogen chloride (HCl). Furthere were measured both the ambient and combustion product temperatures. On basis of these data and other chemical parameters is made calculation of the combustion characteristics: relative loss through sensible heat of the products of combustion and loss through incomplete combustion, combustion heat-technical efficiency and air surplus.

RESULTS AND DISCUSSION

The emission measuring was carried-out for each fuel and took about 4 hours. The CO and NO_x concentration values were scanned in time intervals 60 seconds. From the whole measuring were calculated the average values. As additional quantities were found-out the HCl concentration values, boiler heating output, CO_2 concentration, combustion products temperature and air surplus. Calculated also was the boiler heat-technical efficiency regarding the relative and loss through incomplete combustion. Boiler heat-technical efficiency is defined as:

$$\eta_t = 100 - (q_a + q_b) \ (\%)$$

where: q_a – relative loss through sensible heat of the products of combustion according to so called Siegert's formula (%),
q_b – relative loss through incomplete combustion (%).

The results measuring are presented in Table 3. In Fig. 3 are presented the CO and NO_x emission values in graphical form for all fuels.

From Table 3 and Fig. 3 is evident that CO emissions from utilization of energy sorrel are significantly higher as compared with emissions of other fuels. The limit according to the Czech Government Decree, i.e. 650 mg/m^3 is exceeded for this fuel 4.5 times. For reed canary grass and miscanthus that emission limit is also exceeded but only 1.6 times and 1.3 times, respectively. Very good emission values have been reached for straw combustion because the device is constructed for this material. The low emission values are reached also for knotweed.

All used fuels meet the prescribed limit for NO_x emissions, i.e. emission value until 650 mg/m^3.

CONCLUSIONS

The new energy crops could become in near future a significant heat energy source particularly as a fuel for central heating plants in smaller agglomerations. Their use properties are nevertheless considerably different and it is not possible their mutual replacement or utilization in the combustion device for straw without certain adaptation of the boiler design.

In the case of the energy sorrel, which is unambiguously a prospective energy crop, it can be seen that CO emissions exceed considerably the permitted values during its combustion in the straw boiler. An explanation of that negative phenomenon could be in unsuitable energy sorrel combustion process enabling fast release of the volatile inflammable matter, i.e. share inflammable matter volatilized during standardized coking without air access. To avoid this negative effect there exists a possibility of common combustion of energy sorrel with other materials, e.g. cereal straw.

The contrary example is knotweed, i.e. the crop having very good emission parameters. This crop is not so far included into the cultivation programmes but its properties are a good reason for its practical utilization.

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Emise při spalování energetických bylin

ABSTRAKT: Energetické byliny a odpadní zemědělská biomasa tvoří významný potenciál náhrady fosilních paliv při vytápění. V současné době se využívá sláma, jinými energetickými rostlinami jsou energetický šťovík, chrastice rákosovitá, křídlatka a ozdobnice čínská. Při spalování biomasy jsou sledovány emise CO a NO_x. U pěti druhů paliv byly měřeny emisní parametry při jejich spalování v kotli o výkonu 1 MW. Emise CO jsou u jednotlivých paliv velmi rozdílné. Nejvyšších hodnot bylo dosaženo při spalování energetického šťovíku.

Klíčová slova: energetické rostliny; emise; spalování; vytápění; kotelna; biomasa; energetický šťovík

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