INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND EKOLOGY OF RURAL AREAS

Nr 3/2007, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 79–86
Komisja Technicznej Infrastruktury Wsi

Martin Polák, Pavel Neuberger, Vladimír Šleger

ENERGY SORREL - AN ALTERNATIVE FUEL FOR RURAL AREAS

Summary

The research is focused on energy sorrel as a fuel for local low-power heating systems with output up to 100 kW.

Sorrel is perennial plant surviving in its location nearly 18 years which is very good from the point of crop expenses. It is a robust plant with height of about 2 m in second year of plantation. Dry phytomass is energetically rich fuel with total heating value 17.5 – 18.0 $MJ.kg^{-1}$ at the average yield of 10 tons per hectare.

An experimental combustion of pure sorrel and its blends were done with boiler VERNER A25 – a hot water boiler for pellets. 11 different sorrel fuels consisting of 5 primary kinds were tested during the experiment: sorrel (*Rumex tianshanicus* x *Rumex patientia*), *Phalaroides arundinacea*, *Canabis sativa*, pine-bark, sorrel (*Rumex tianshanicus* x *Rumex patientia*), brown coal.

Based on collected data it is possible to obtain an overview of these fuels and their emission properties. Satisfactory values of CO concentration are possible to gain partly by choosing appropriate combustion device and its settings and partly by mixing with other types of fuel. In the case of sorrel the combination of both has been shown very useful. It is very hard to combust sorrel only, and its testing proves unsatisfactory results. But if we combust blend of sorrel and canary grass 1:1 in the same device, the results are somewhat better. The best results can be reached if we burn this blend in more suitable device. By this way it is even possible to fulfil the emission limits. However, if we burn only pure sorrel in another burner, the emissions are very dissatisfactory again. Another possibility of how to burn sorrel effectively is to combine it with brow coal. On the basis of received results, fuel containing 10 to 20 % of coal can be recommended.

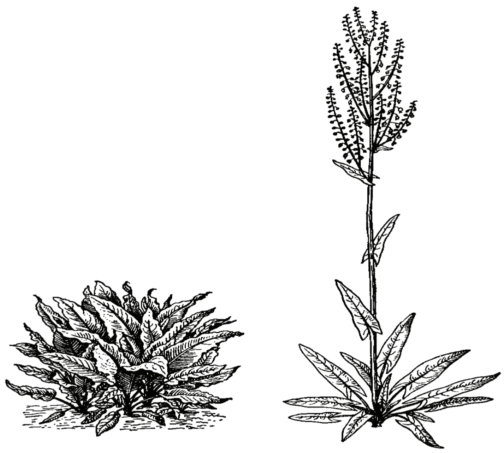
From point of view of ash properties pure sorrel appears a problematic fuel. During our experiment ash accumulation in combustion chamber was observed. Unburnt fuel blocked air intakes which caused burning deterioration and increase of CO emissions.

All above mentioned facts indicate that sorrel burning is possible if we fulfil all demands required for this fuel. Combustion of pure sorrel in any device without special settings means in many cases non effective use of fuel and bad emissions.

Key words: sorrel, combustion, emission

INTRODUCTION

Alternative fuels based on energy plants are extending, especially in last years. Besides wood, which is mostly used in small boilers, there are some non-traditional biofuels – energy plants and agricultural by-products. One of the most popular is energy sorrel. This plant is an arable crop cultivated in Ukraine as a hybrid of *Rumex tianshanicus* and *Rumex patientia*. Sorrel is a perennial plant living in its location nearly 18 years which is very good from the point of crop expenses. It is a robust plant with the height of about 2 m in the second year of plantation. Substantial importance of sorrel is in its phytoenergy purposes, i.e., direct combustion. Dry phytomass is energetically rich fuel with total heating value of 17.5 – 18.0 MJ.kg^{-1} at an average yield of 10 tons per hectare.



a) 1st year b) 2nd year

Figure 1. Energy sorrel (Rumex tianshanicus x Rumex patientia)

MATERIALS AND METHODS

Experimental combustion

An experimental combustion of pure sorrel and its blends were done with boiler VERNER A25. VERNER A25 is a hot water boiler for pellets supplied with screw conveyer through back side of combustion chamber. Plate bottom of the chamber is equipped with a saw-like grate bar which removes ash in adjusted cycles. The side and upper walls are covered with ceramic slabs. Air is forced by the fan under the grate as a primary and through side walls as secondary.
Modifications are following:

G ... original boiler, without any modification

H ... modified boiler, enlarged combustion chamber and redistribution of air inlets

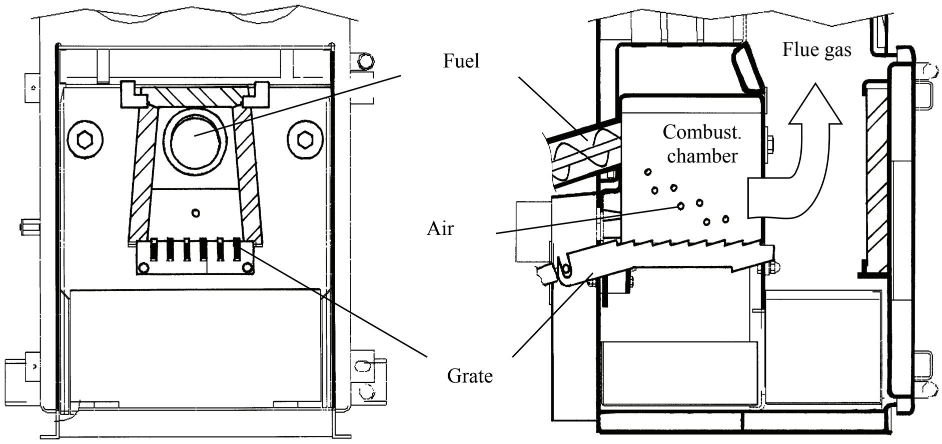


Figure 2. Hot water boiler VERNER A25

Testing equipment

Continual record of emission parameters was obtained with TESTO 350XL analysis box. Heat power output can be determined from water flow and temperature at the output and input of the boilers.

The resultant value is determined as a median with fractile characteristic of gained dates. Data were processed by means of statistic software R 2.0.1.

All presented results are recounted for 11% O_2 content in flue gases.

Used fuels

11 different sorrel fuels consisting of 5 primary kinds were tested during the experiment: sorrel (Rumex tianshanicus x Rumex patientia), Phalaroides arundinacea, Canabis sativa, pine-bark, sorrel (Rumex tianshanicus x Rumex patientia), brown coal.

Elementary analyses of each one fuel were done before combustion testing. All properties are below in table 1 and 2.

Table 1. Fuel properties

Sample number	Fuel composition	Water	Volatile combustible	Involatile combustible	Ash	Total heating value	Fuel value	C	H	N	S	O	Cl
		[%]	[%]	[%]	%]	[MJ/kg]	[MJ/kg]	[%]	[%]	[%]	[%]	[%]	[%]
1	sorrel II	12.5	63.8	18.5	5.2	16.07	14.68	44.0	6.4	1.0	0.3	30.5	0.08
2	sorrel+5%coal	8.5	65.7	19.0	6.8	17.16	15.67	44.3	5.9	0.8	0.1	33.5	0.08
3	sorrel+10%coal	8.2	65.8	19.3	6.7	17.11	15.64	43.7	5.8	0.8	0.1	34.6	0.11
4	sorrel+20%coal	8.1	64.1	20.6	7.2	18.02	16.51	47.6	6.1	0.8	0.2	30.1	0.11
5	sorrel+30%coal	7.9	63.5	20.6	8.1	18.52	17.07	46.8	5.8	0.9	0.2	30.4	0.09
6	sorrel+Phalaroides arund. 1:1	5.7	70.6	17.1	6.6	17.32	15.94	42.4	5.7	0.8	0.1	38.5	0.19
7	sorrel+canabis sativa 1:1	8.2	69.6	16.5	5.7	16.84	15.37	42.7	5.9	0.7	0.1	36.5	0.29
8	sorrel+bark 1:1+10%coal	9.2	64.2	20.5	6.1	17.57	16.05	44.8	6.0	0.7	0.1	33.0	0.07
9	sorrel+bark 3:1+10%coal	10.0	65.0	19.4	5.7	17.43	15.89	45.0	6.0	0.7	0.1	32.5	0.09
10	sorrel+coal 1:1	7.6	53.7	26.0	12.0	19.05	17.7	47.8	5.4	0.6	0.5	26.1	0.07
11	sorrel+coal 35:65	7.8	66.3	11.7	14.3	19.6	18.26	49.1	5.3	0.7	0.7	22.1	0.06

Tabela 2. Ash properties

Sample number	Fuel composition	Softening point	Melting point	Creep point
		[°C]	[°C]	[°C]
1	sorrel II	1240	1250	1260
2	sorrel+5%coal	1040	1210	1230
3	sorrel+10%coal	1160	1210	1220
4	sorrel+20%coal	1290	>1290	>1290
5	sorrel+30%coal	1080	1230	>1290
6	sorrel+Phalaroides arund. 1:1	1140	1150	1160
7	sorrel+canabis sativa 1:1	1200	1210	1220
8	sorrel+bark 1:1+10%coal	1260	1270	1280
9	sorrel+bark 3:1+10%coal	1280	1290	>1290
10	sorrel+coal 1:1	1270	1280	1290
11	sorrel+coal 35:65	1220	1220	1230

RESULTS AND DISCUSSION

The fuels are similar in many aspects. Satisfactory values of CO concentration are possible to gain partly by choosing the appropriate combustion device and its settings, and partly by mixing with other types of fuel. In the case of sorrel, the combination of both has been shown very useful. It is very hard to combust only sorrel, and its testing proves unsatisfactory results. But if we combust blend of sorrel and canary grass 1:1 in the same device, the results are somewhat better. The best results can be reached if we burn this blend in more suitable device (modification H in our case). By this way it is even possible to fulfil the emission limits. However, if we burn only pure sorrel in modification G, the emissions are very dissatisfactory again. Another possibility of how to burn sorrel effectively is to combine it with brow coal. But according to increasing concentration of NO_x and SO_2 with higher proportion of coal it is necessary to consider this possibility. On the basis of received results, fuel containing 10 to 20% of coal can be recommended. Total emission parameters are shown in Fig. 3.

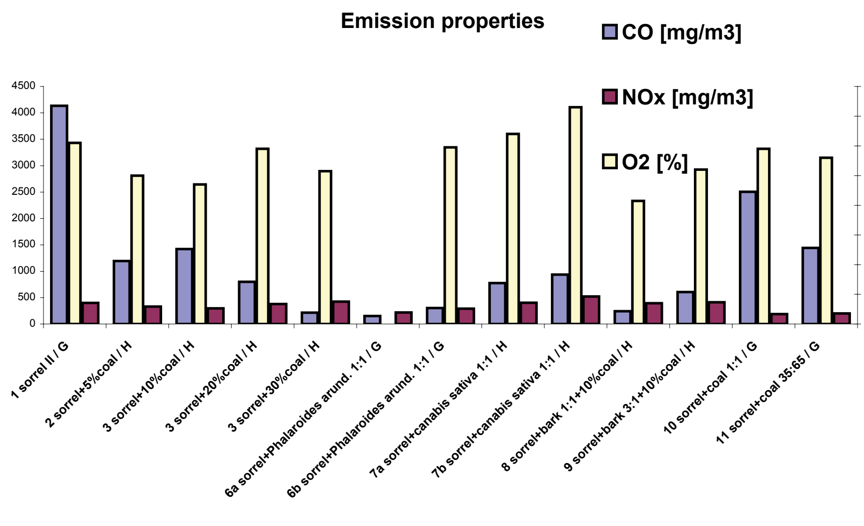


Figure 3. Total emission for each fuel

Typical course of CO emission record during experimental testing can be seen in Fig. 4. Pure sorrel has non-stabile course with great dispersion of values. An addition of higher proportion of coal means better stability and lower CO level.

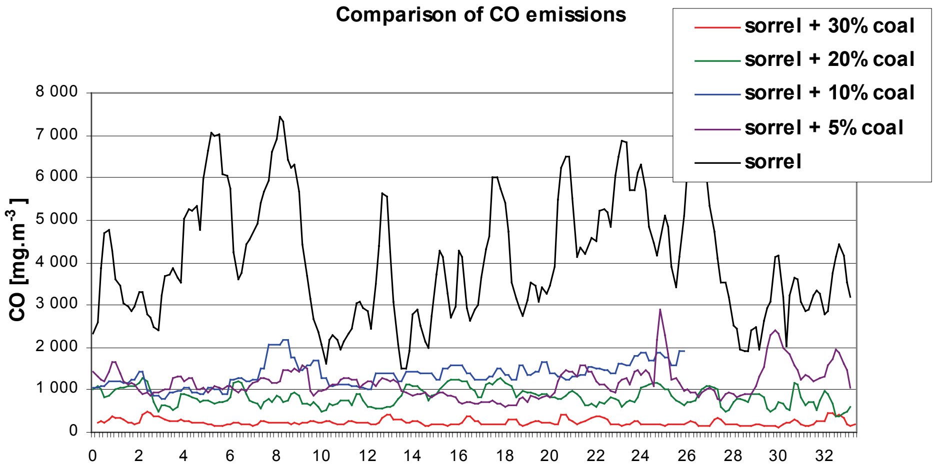


Figure 4. CO emissions in sorrel with addition of different proportion of coal

Figure 5. Detailed view into the burner at the end of pure sorrel combustion

On the basis of fuel analyses it is possible to say that the heat of combustion of every sample is in the range of 16–19 MJ.kg-1 and does not differ significantly one from another. Heating value of biofuels will be thus determined mainly by the content of water in the fuel. The content of volatile combustible falls into the range of 54 to 70%. An exception are blends with higher coal proportion which have low portion of volatile combustible, and wood on the other hand that contains high amount of volatile combustible.

From point of view of ash properties pure sorrel appears as a problematic fuel. During our experiment ash accumulation in combustion chamber was observed. The unburnt fuel blocked air intakes causing burning deterioration and increase of CO emissions. Situation in the burner in the end of combustion can be seen in Fig. 5.

If we want to assess combustion devices then the best results were reached with the ones that were constructed with adequately large, non-cooled space for burning of volatile combustible and with suitably designed inlets of air. In our case it was modification H. This result is in good accordance with our theoretical presumptions.

CONCLUSIONS

All above mentioned facts indicate that sorrel burning is possible if we fulfil all demands which this fuel has. Combustion of pure sorrel in any device without special settings means in many cases non effective use of fuel and bad emissions. Satisfactory results can be achieved with fuel blending and choosing and setting of optimal burner parameters. Renewability of this fuel make it as a source that can be count on in the future. But even there still remain many unsolved questions that will be apparently subject of further research in this field.

This article was created within the scope of project of National Agency of Agriculture Research No. QG60083: "Competition of bioenergy products"

REFERENCES

Pastorek, Z.; Kára, J.; Jevič, P.: *Biomasa – obnovitelný zdroj energie*. FCC PUBLIC Prague, Prague 2004, 288 s. ISBN 80-86534-06-5.

Pastorek, Z. et al.: *Využití odpadní biomasy rostlinného původu.* Metodiky pro zemědělskou praxi. ÚZPI MZe ČR, Prague 1999, 72 p.

Kára, J.; Šrámek, V.; Hutla, P.; Stejskal, F.; Kopnická, A.: *Využití biomasy pro energetické účely*, ČEA Prague , Prague 1997, 108 p.

Jevič, P.; Šedivá, Z.; Sladký V.: *Emise při energetickém využití biomasy*, Energie l/98, Prague.

Hrdlička, F.: *Biomasa – zdroj obnovitelné energie*. Professor lectures. CTU Prague 2003. Prague. 28 s. ISBN 80-01-02830-5.

Polák, M.: *Biomass for heat production*. PhD thesis, CUA Prague 2005, 113 p.

Polák, M.: Phytomass as a fuel for small scale boilers. In: *Naukovyj visnik NAU 73/2004*. Kyiiv 2004, s. 246 – 252, ISBN 966-8302-07-9.

Polák, M.: The practical experience with phytomass combustion in small scale boilers. In: *Collection of abstracts of International conference – Science and research – Tools of global development strategy*, CUA in Prague, 2004. s. 38, ISBN 80-213-1187-8.

Ing. Martin Polák Ph.D., Ing. Pavel Neuberger Ph.D., doc. Ing. Vladimír Šleger CSc.
Czech University of Life Science,
Department of Mechanics and Engineering,
165 21 Praha 6 – Suchdol, Czech Republic,
e-mail: karel@tf.czu.cz

Reviewer: *Prof. Jerzy Gruszczyński, Dr.Sc., Ph.D*