ALTERNATIVE FUELS – AGRICULTURAL WASTE MATERIALS UTILIZATION

ALTERNATIVNÍ PALIVA – MOŽNOSTI VYUŽITÍ ODPADŮ ZE ZEMĚDĚLSKÉ ČINNOSTI

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MALAŤÁK, J. – KARANSKÝ, J. – ALTMAN, V. – JAVIČ, P. – GÁLIK, R.: Alternative fuels – agricultural waste materials utilization. Agriculture (Poľnohospodárstvo), vol. *53*, 2007, N. 1, pp. 38–48.

The article is concerned with energy production from the heat-processed selected agricultural wastes. It means the possibility to use the wastes, solid biomass, alternative and standardized firings as the fuels for heat power plants.

Within this experimental project, seventeen analyses of selected mixed wastes from agricultural production were carried out. The wastes are mostly formed into the pellets. These are then analyzed in details in order to find out the chemical and stoichiometric composition and energy balance. Mixed and pelleted fuels from the agricultural wastes have a different structure and parameters. It mostly results from the different concentrations of element compositions in waste mixtures. Some negative characteristics of water and ash matter content follow from the elemental analysis and stoichiometric calculations. From the view of emission concentrations, the amounts of sulphur, nitrogen and chlorine in wastes are the most important parameters. Solving of this up-to-date problem contributes to emission reduction and in this way also to air pollution reduction.

Key words: biomass, alternative fuels, agricultural wastes, elemental analyses, stoichiometric calculations

The importance of renewable energy resources shoots up with the predicted exhaustibility of fossil energy sources. It becomes one of the main conditions of sustainable development, not only in agriculture, but also in the whole society. It is declared that the worldwide share of vegetable biomass (mostly wood) in the total consumption of primary power sources has increased by about 8 % over the last twenty years. This increase is common not only in developing countries, where the wood is often the only source of energy, especially in rural areas. In some developing countries, four fifths (80 %) of cut wood are used as a fuel. However, the firewood consumption is also growing in developed countries [2, 11, 12, 13].

The increase of renewable energy sources became the priority of the 6th Framework pro-

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gramme in the area of energy and transportation (thematic priority 6) within EU. It led to the financing of research within the framework of big integrated projects. The leading European producers of energy equipments and vehicles were involved in these projects as well [13, 14, 15].

Solid recovered fuels are quite frequently discussed problem at present. The Czech equal term „tuhá alternativní paliva“ from English “solid recovered fuels” or German „feste Sekundärbrennstoffe“ is covered by the Czech norm ČSN CEN/TR 14980 *Solid recovered fuels – Report of mutual difference among biologically decomposable and biogenous elements of solid recovered fuel components* [1, 3]. It takes into account the contemporary legal regulation of wastes utilization as fuels. It is covered by several laws, the concerned laws are especially the laws about wastes, packing and atmosphere. Solid recovered fuels are the fuels produced directly or indirectly from the biomass. It means, these fuels might have a biomass basis, therefore the norm ČSN CEN/TR 14980 [3] has been created. Regarding the norm creation, the solid recovered fuels are ranked among the solid fuels, e.g. ČSN ISO 1213-2 [4] and among the solid biofuels, e.g. ČSN CEN/TS 14588 [3].

Solid recovered fuels are produced from the safe waste, which is used for energy recuperation by burning or by communal burning of materials, regulated by the European Community environmental legislation [8, 9].

The solved problem has the worldwide importance due to the rapid increase of fuel use, renewable energy sources, and biomass. Solution will bring a definite classification and specification principles of using agricultural wastes. This classification and specification provide them acceptability on the fuels market and increase in public confidence. It also precipitates compulsory approval procedures, exchange of information about the use of solid biofuels and alternative fuels from renewable sources, and associated environmental problems.

When using the agricultural wastes for energy recuperation, it is necessary to accentuate ecology of operation of these plants. Therefore it is necessary to take the chemical composition analyzes, operation parameters, ash matter and stoichiometric calculations of the combustion equipment as a basis.

All the kinds of solid fuels, occurring in natural (raw) condition, are composed of three main components: total water content, ash matter and combustibles. This composition can be expressed by the following formula

$$\sigma(W_t^r) + \sigma(C_t^r) + \sigma(H_t^r) + \sigma(O^r) + \sigma(S_t^r) + \sigma(N^r) + \sigma(A_t^r) = 100\ \% \qquad [1]$$

where $\sigma(W_t^r)$, $\sigma(C_t^r)$, $\sigma(H_t^r)$, $\sigma(O^r)$, $\sigma(S_t^r)$, $\sigma(N^r)$, $\sigma(A_t^r)$ are weight shares of total water, oxygen, carbon, hydrogen, sulphur, nitrogen and ash amount in original sample (all parameters in weight %).

Water and ash matter are non-flammable parts of fuel, described as the ballast or deadwood. Both of them decrease heating power of fuel. Their presence has a direct effect on combustion equipment construction and they often cause some problems during operation.

A flammable part of the fuel consists of carbon, hydrogen, sulphur and nitrogen. Only carbon, hydrogen and sulphur are involved in exothermic reactions with air oxygen, i.e. in burning. Oxygen in fuels works as an oxidant and nitrogen is the only component which is not involved in burning [10, 14].

All of the main three fuel components (water, ash matter and combustibles) are very important factors in combustion process. Their properties influence construction of combustion equipment as well s its operation regime.

Determination of elemental analyses, stoichiometric analyses, and emission parameters of selected wastes is carried out on compressed or loosely spread agricultural wastes. These can be compressed into the different shapes by using various pressures.

There are also used compressed materials in a form of pellets. If biofuels are not compressed, they take too much space and increase transportation, manipulation and storage costs. During firing, they reach a fast ignition and only a small amount of specific heat is transmitted. On the other hand, parameters of compressed biofuels are more profitable and they last longer in a hearth during combusting as compared to uncompressed fuels.

MATERIAL AND METHODS

A particle analysis of selected agricultural wastes was done within the framework of the research project. These biomaterials are described in table 1. For comparison of selected materials, two referential fuels, no.1 and no. 2, have been chosen.

The elemental analysis was done for selected wastes in order to set the basic parameters of fuels. Mostly focused on [7]

- water content (weight %);
- ash matter (weight %);
- volatile and unvolatile combustibles (weight %);
- combustion heat ($MJ.kg^{-1}$);
- heating power ($MJ.kg^{-1}$);
- $CO_{2\ max}$ (weight %);
- carbon (weight %);
- hydrogen H (weight %);
- nitrogen N (weight %);
- sulphur S (weight %);
- oxygen O (weight %);
- chlorine Cl (weight %).

Particle composition of fuels has an influence on all stoichiometric calculations. These include heat efficiency, heat loss of combusting equipments, and other parameters. The mentioned parameters also have significant influence on thermal work of combusting equipment.

The fixed elemental analysis was set by the elementary analyzer multi-EA for determination of C, N, S and Cl (producer ChromSpec), by chromatograph GC-MS for detection of combustible

T a b l e 1

Selected materials – agricultural wastes
Vybrané materiály – odpady ze zemědělské činnosti

Sample no. (1)	Selected materials – agricultural wastes (2)	Diameter (mm) (3)
1	black coal – slack coal (referential sample) (4)	
2	brown coal – nut 2 (referential sample) (5)	
3	cereal straw and energy sorrel in a ratio 1:1 (pellets) (6)	10
4	cereal straw energy sorrel in a ratio 1:1 (pellets) (7)	10
5	cereal straw and *Phalaris arundinacea* in a ratio 1:1 (pellets) (8)	10
6	cocoa bean shell (9)	
7	fermented waste treatment mud and hay in a ratio 1:1 (pellet)s (10)	10
8	cocoa bean shell (pellets) (11)	20
9	cereal straw (pellets) (12)	10
10	meat and bone meal (pellets) (13)	20
11	cereal straw a rapeseed straw in a ratio 1:1 and treacle (pellets) (14)	15
12	mustard straw (pellets) (15)	20
13	Ekobiopal (fermented mixture – 33 % rotten fermented waste treatment mud and 67 % wood chips) (pellets) (16)	10
14	cleaning cereals residues (pellet (17)	8
15	cleaning cereals residues and grass in a ratio 1:1 (pellets) (18)	20
16	cereal straw (pellet) (19)	20
17	meat and bone meal and energy sorrel in a ratio 1:1 (pellets) (20)	20
18	cereals cleaning residues and energy sorrel in a ratio 1:1 (pellets) (21)	20
19	fermented waste treatment mud and energy sorrel in a ratio 1:1 (pellets) (22)	20

(1) Číslo vzorku, (2) vybrané materiály – odpady ze zemědělské činnosti, (3) průměr, (4) černé uhlí – krupice praná (referenční vzorek), (5) hnědé uhlí – ořech 2 (referenční vzorek), (6) sláma obilní a energetický šťovík v poměru 1:1 (pelety), (7) sláma obilní a energetický šťovík v poměru 1:1 (pelety), (8) sláma obilní a chrastive v poměru 1:1 (pelety), (9) kakaové slupky, (10) fermentační čistírenské kaly a luční seno v poměru 1:1 (pelety), (11) slupky z kakaových bobů (pelety), (12) pelety z obilné slámy, (13) masokostní moučka (pelety), (14) sláma obilní a sláma řepková v poměru 1:1 a melasa (pelety), (15) sláma hořčice (pelety), (16) Ekobiopal (fermentovaná směs – 33 % vyhnilého čistírenského kalu a 67 % dřevní štěpky) (pelety), (17) zbytky po čištění obilí (pelety), (18) zbytky po čištění obilí a tráva v poměru 1:1 (pelety), (19) pelety z obilné slámy, (20) masokostní moučka a energetický šťovík v poměru 1:1 (pelety), (21) zbytky po čištění obilí a energetický šťovík v poměru 1:1 (pelety), (22) fermentační čistírenské kaly a energetický šťovík v poměru 1:1 (pelety)

components (producer Perkin Elmer), and calorimeter IKA-C4000 (producer IKA Laboratory and Analytical Equipment) for determination of combustible heat and heating power samples.

Final values are presented in table 2. The elemental analysis is a necessary part of measurements to determine the basic stoichiometric and thermal properties of evaluated fuels.

An important task of the research project is to set agricultural wastes stoichiometry. Stoichiometric calculations of combustion processes supplement fuels characteristics and are also the basis for any heat calculation. These are very important for solving various problems of design practice, as well as for checking the heat equipment operation. The following parameters are determined by these calculations:

- fuel heating power;
- theoretical amount of oxygen and air necessary for ideal combustion, real air amount of ideal combustion;
- mass and volume amount of waste gases (wet and dry);
- theoretical amount of mass and volume dry waste gases;
- mass and volume amount of CO_2, SO_2, H_2O, N_2, O_2 and argon;
- theoretical weight and volume concentration of CO_2 and SO_2 in dry waste gases;
- each waste gas particle, explicated in weight and volume % [6].

Agricultural wastes heating power is set by calculation based on the measured combustion heat and elemental analyses. Combustion heat is measured in calorimeters [5]. The relation between combustion heat Q_s^r and heating power Q_i^r can be described as a formula [5]

$$Q_i^r = Q_s^r - (0{,}02442 \cdot 1000) \cdot [s(W_t^r) + 8{,}94 \cdot s(H_t^r)] \quad (kJ.kg^{-1},\ kJ.m^{-3}_N) \qquad [2]$$

where $\sigma(W_t^r)$ – water content of analyzed sample (%)

8.94 – recalculation hydrogen coefficient

$\sigma(H_t^r)$ – hydrogen content of analyzed sample (%)

0.02442 – value corresponding to the energy used for heating the amount of 1 % of water at 25°C

Setting of mass combustion:

- theoretical oxygen amount for ideal combustion:

$$O_{min} = \frac{32}{12} \cdot C + \frac{32}{4} \cdot H + \frac{32}{32} \cdot S - \frac{32}{32} \cdot O \quad (kg.kg^{-1}) \qquad [3]$$

- theoretical air amount for ideal combustion:

$$L_{min} = O_{min} \cdot \frac{100}{23{,}2} \quad (kg.kg^{-1}) \qquad [4]$$

- theoretical amount of dry waste gases during ideal combustion:

$$m^s_{spmin} = \frac{44}{12} \cdot C + \frac{64}{32} \cdot S + N + 0.75474 \cdot L_{min} \quad (kg.kg^{-1}) \qquad [5]$$

where C, H, O, S, N, W – proportional amounts of carbon, hydrogen, oxygen, sulphur, nitrogen and all the water content in original fuel ($kg.kg^{-1}$)

n – air surplus coefficient (absolute value)

- the expression of theoretical mass concentration of carbon dioxide contained in dry waste gas:

$$CO_{2max} = \left(\frac{44}{12} \cdot C\right) \cdot {m^s_{spmin}}^{-1} \cdot 100 \quad (weight\ \%) \qquad [6]$$

Setting of mass combustion *(*values of real molecular gas mass*):*

- theoretical oxygen amount for ideal combustion:

$$O_{min} = \frac{22.39}{12.01} \cdot C + \frac{22.39}{4.032} \cdot H + \frac{22.39}{32.06} \cdot S - \frac{22.39}{31.99} \cdot O \quad (m^3_N.kg^{-1}) \qquad [7]$$

- theoretical air amount of ideal combustion:

$$L_{min} = O_{min} \cdot \frac{100}{21} \quad (m^3_N.kg^{-1}) \qquad [8]$$

– dry waste gas theoretical amount:

$$V^s_{spmin} = \frac{22.27}{12.01} \cdot C + \frac{21.89}{32.06} \cdot S + \frac{22.40}{28.013} \cdot N + + 0.7805 \cdot L_{min} \quad (m^3_N.kg^{-1}) \quad [9]$$

where C, H, O, S, N, W – proportional amounts of carbon, hydrogen, oxygen, sulphur, nitrogen and all the water content in original fuel ($kg.kg^{-1}$)
n – air surplus coefficient (absolute value)

– the expression of theoretical mass concentration of carbon dioxide contained in dry waste gas:

$$CO_{2max} = \left(\frac{22.27}{12.01} \cdot C \right) \cdot v^{s\ -1}_{spmin} \cdot 100 \text{ (vol. \%)} \quad [10]$$

Stoichiometric calculations are recalculated by the weight of total water amount contained in selected samples. Values are also recalculated by the air surplus coefficient for normal conditions (at the temperature t = 0°C and pressure p = 101.325 kPa) as well as for the referential oxygen amount in combustibles O_r = 11 %.

RESULTS AND DISCUSSION

The most determining factor of thermal use of fuels is water and ash matter content. Water content in wastes ranged from 5.02 weight % in cereal straw and energy sorrel mixture up to 11.16 weight % of total water in fermentation sediments with biomass and energy sorrel mixture. There are obvious possibilities of fuels different usage according to the water content and heating power. Ash matter is other non-flammable component. Ash matter is a solid residue, obtained by ideal burning of solid fuel at the temperature of 800 ± 25°C in oxidizing atmosphere. The ash matter content is low, as

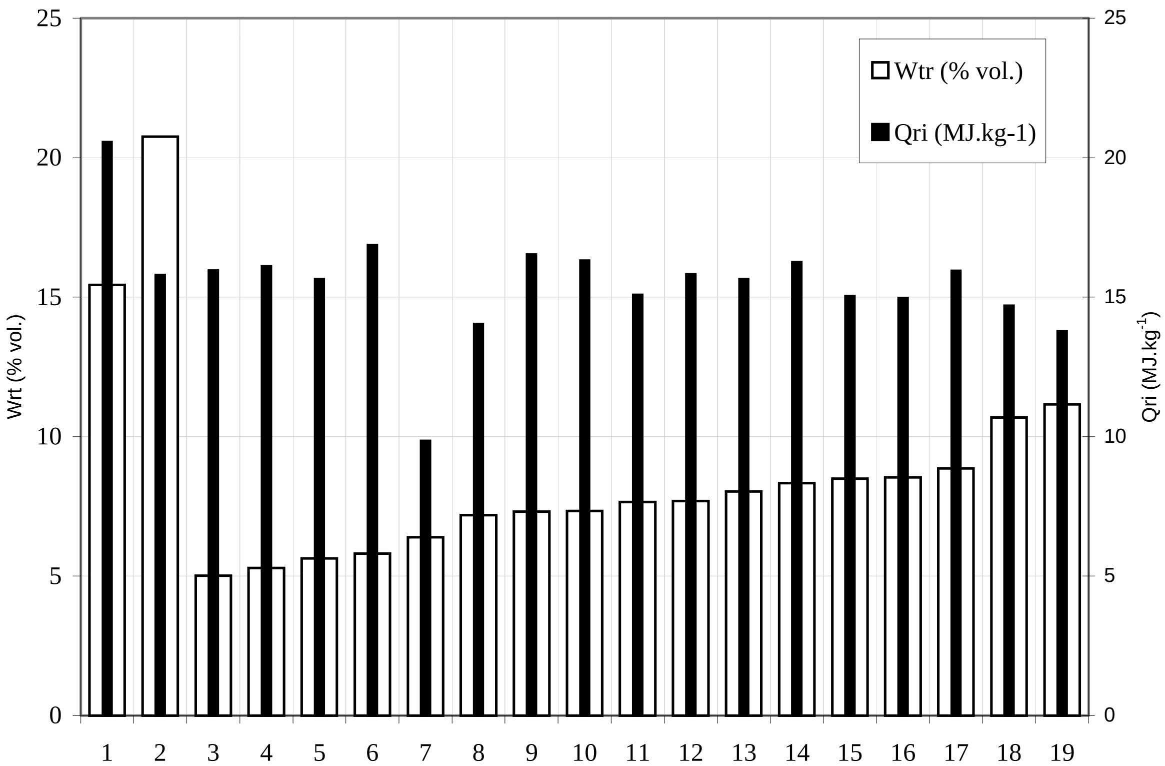

Fig. 1. Final heat values of selected mixed wastes samples
Obr. 1. Výsledné tepelné hodnoty vybraných vzorků směsných odpadů
W^r_t – water content – obsah vody
Q^r_i – heat power – výhřevnost
1-19 – samples – vzorky

can be seen from elemental analyses (tab. 2). Plant trash has the lower content of ash matter than the brown coal – by 86 % less. It has the following positive effects: the amount of solid ash particles emission during burning is smaller and the amount of solid residues is also significantly smaller. The smallest amount of ash matter was obtained by the burning of cereal puri-

T a b l e 2

Final values of selected agricultural wastes elemental analyses
Výsledné hodnoty prvkových rozborů vybraných odpadů ze zemědělské činnosti

Sample no. (1)	Parameters of elemental analyses (2)												
	W^r_t	A^r	V^r	$(NV)^r$	Q^d_s	Q^r_i	CO_{2max}	C^r_t	H^r_t	N^r_t	S^r_t	O^r_t	Cl^r_t
	% vol.				MJ.kg^{-1}		% vol.						
1	15.44	17.76	–	–	21.67	20.56	18.55	54.21	3.34	0.78	3.09	5.38	–
2	20.76	20.44	–	–	17.23	15.79	17.36	42.31	4.24	0.58	3.85	7.81	–
3	5.02	7.48	71.20	16.30	17.21	15.95	20.10	41.88	5.35	0.65	0.12	39.40	0.10
4	5.29	6.74	71.48	16.49	17.41	16.1	19.74	42.96	5.42	0.67	0.11	38.70	0.11
5	5.64	8.14	70.65	15.57	17.03	15.65	19.78	41.95	5.71	0.68	0.09	37.65	0.14
6	5.81	8.04	65.17	20.98	18.17	16.86	20.30	38.79	5.39	1.96	0.24	39.75	0.02
7	6.39	39.61	49.88	4.12	10.69	9.85	17.30	27.80	3.88	1.85	0.77	19.58	0.12
8	7.18	13.10	63.06	16.66	15.49	14.04	18.51	41.73	5.86	2.32	0.10	29.63	0.08
9	7.31	3.99	72.15	16.55	17.96	16.53	19.53	46.54	5.71	0.19	0.09	35.97	0.2
10	7.33	19.90	63.56	9.21	17.75	16.31	18.95	41.32	6.63	8.85	0.66	14.93	0.38
11	7.66	7.27	69.99	15.08	16.57	15.08	19.25	42.24	5.99	0.95	0.14	35.55	0.20
12	7.69	7.50	68.29	16.52	17.32	15.82	19.01	43.10	6.05	1.48	0.13	33.96	0.09
13	8.04	12.12	63.29	16.55	16.91	15.64	19.92	42.47	4.90	1.18	0.28	31.01	–
14	8.33	6.49	71.16	14.02	17.86	16.25	18.3	42.62	6.48	3.67	0.16	32.05	0.20
15	8.49	9.5	66.63	15.38	16.54	15.04	18.47	41.02	5.95	1.44	0.13	33.37	0.10
16	8.54	8.49	67.42	15.55	16.30	14.97	20.30	41.56	5.15	0.64	0.07	35.55	–
17	8.86	12.39	65.10	13.65	17.36	15.94	16.12	42.82	6.53	4.79	0.48	23.89	0.24
18	10.69	5.59	64.53	19.19	16.09	14.69	18.30	42.57	6.44	1.36	0.21	33.01	0.10
19	11.16	11.8	60.09	19.65	15.02	13.77	18.35	39.56	5.76	1.39	0.55	29.66	0.12
Statistic analysis of samples no. 3–19 (3)													
$\bar{x}$	7.61	11.07	66.10	15.381	16.57	15.21	18.95	41.231	5.72	2.00	0.25	31.98	0.15
s^2	2.94	67.93	30.43	15.107	3.04	2.62	1.25	14.622	0.47	4.45	0.05	47.68	0.01
s	1.71	8.24	5.52	3.887	1.74	1.62	1.12	3.824	0.69	2.11	0.22	6.90	0.10
v	0.23	0.74	0.08	0.253	0.11	0.11	0.06	0.093	0.12	1.05	0.86	0.22	0.66
+/-	0.84	4.04	2.70	1.905	0.85	0.79	0.55	1.874	0.34	1.03	0.11	3.38	0.05

W^r_t – water content – obsah vody
A^r – ash matter – popel
V^r – volatile combustible – hořlavina prchavá
$(NV)^r$ – involatile combustible – hořlavina neprchavá
Q^d_s – combustion heat – spalné teplo
Q^r_i – heat power – výhřevnost
CO_{2max} – carbon dioxide – oxid uhličitý
C^r_t – carbon – uhlík
H^r_t – hydrogen – vodík
N^r_t – nitrogen – dusík
S^r_t – sulphur – síra
O^r_t – oxygen – kyslík
Cl^r_t – chlorine – chlór
$\bar{x}$ – average – průměr
s^2 – variance – rozptyl
s – standard deviation – směrodatná odchylka
v – coefficient of variance – variační koeficient
+/– – confidence interval – konfidenční interval

(1) Číslo vzorku, (2) parametry prvkového rozboru, (3) statistické vyhodnocení vybraných vzorků odpadů č. 3–19

fication residues and sorrel mixture. The highest amount was obtained by the burning of fermentation sediments with biomass. These large fluctuations in water and ash matter contents are significant characteristics of selected wastes. Final heat values are presented in figure 1. The other differences of fuels are obvious from table 2. Especially amounts of volatile and involatile combustibles, carbon, nitrogen, oxygen, and frequently discussed chlorine. These differences in fuels compositions influence both the use and the setting of combustion equipment.

From the results of stoichiometric analysis, the differences in air consumption and in the amounts of produced dry emissions, when burning selected wastes, are obvious (fig. 2). Most significant emission factors are sulphur and chlorine amounts, contained in selected wastes.

Significantly high increase of nitrogen emissions can be seen at the mixed wastes based on plant biomass since. These energy plants have higher values of nitrogen in the fuel. This is a cause of their limited use. Also the most of chlorine amount pass to gaseous phase during combustion. Importance of this element consists in production of HCl emissions and their possible effect on production of both polychlorinated dibenzo-dioxines and furans (PCDD/F), and on the other hand, in corrosive effects of these elements or their compounds.

Also most of sulphur passes to gaseous phase as SO_2 or SO_3 during burning. Sulphur emissions are not a problem for biomass combustion equipments as to the limit values (see tab. 2 and 4). However, corrosive activity of sulphur can be a decisive factor. Final values of particular components of fuel gas are presented in table 3.

The choice and design of combustion equipment are influenced by the fuel stoichiometry and other fuel parameters, such as heating power, water content, and energy density. Analyses of selected samples confirm a wide range of nitrogen, sulphur, and chlorine concentrations in the wastes. Oxygen is a problematic part of the fuel, because of hydrogen and partly carbon binding, creating hydroxides, water, and other oxides. Oxides are mainly connected with nitrogen (in a form of amines and proteins contained in fuels) and chlorine. There is an interaction of chlorine oxides with conversion equipment, especially with combusting equipment [10, 14].

Humidity affects the combustion process and

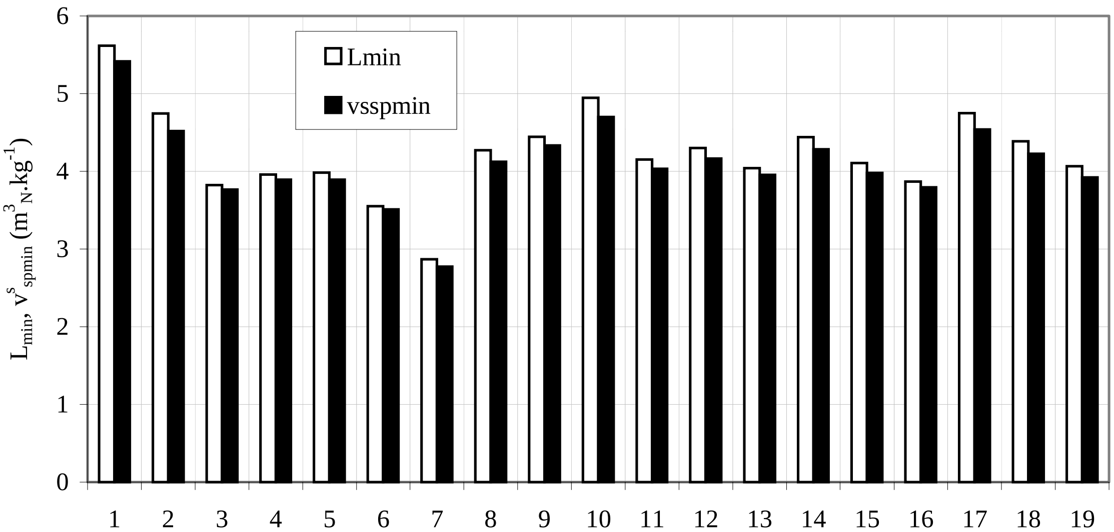

Fig. 2. Final combusting values of selected mixed wastes
Obr. 2. Výsledné spalovací hodnoty vybraných vzorků směsných odpadů
L_{min} – theoretical air quantity for ideal combustion process
– teoretické množství vzduchu pro dokonalé spalování
V^s_{spmin} – theoretical volume of dry combustion gases – teoretické objemové množství suchých spalin
1–19 – samples – vzorky

volume of waste gases produced per energy unit. Generally could be stated that the amount of wooden pellets should not exceed 30 %. In the case of straw, 20 % humidity is acceptable, however, the smaller is the combusting equipment, the drier fuel has to be used. Problems arise during a long-term storage of wet biofuels as well as self-ignition of wooden pellets with humidity over 27 %. This feature is connected with the loss of dry matter, energy value, and risk of fungi. If the average humidity of straw exceeds 17 %, there is a high risk of local achievement of organic powder, endotoxins, and excess mycoses [10].

The most limiting factors for the heat use of judged wastes are water and ash matter amounts. From the tested samples of agricultural wastes, better parameters have been found out at:

– cereal straw and energy sorrel mixed in ratio 1:1 (pellets);
– cereal straw – canary grass in ratio 1:1 (pellets);
– cocoa bean shells;

T a b l e 3

Final values of the individual combustion components
Výsledné hodnoty jednotlivých složek spalin

Sample no. (1)	Combustion components (2)									
	volume concentration of volume amount of wet burnt gas elements (3)					volume amount of burnt gas elements (4)				
	CO_2	SO_2	H_2O	N_2	O_2	v_{CO2}	v_{SO2}	v_{H2O}	v_{N2}	v_{O2}
	% vol.					$m^3N.kg^{-1}$				
1	6.41	0.13	7.32	73.11	12.17	10.1	0.02	1.15	11.25	1.92
2	5.84	0.19	9.09	72.03	11.99	0.79	0.03	1.23	9.73	1.62
3	7.04	0.01	9.56	70.78	11.78	0.78	0.00	1.06	7.84	1.31
4	6.98	0.01	9.47	70.91	11.80	0.80	0.00	1.08	8.12	1.35
5	6.78	0.01	9.74	70.85	11.79	0.78	0.00	1.12	8.17	1.36
6	6.97	0.02	10.08	70.40	11.70	0.72	0.00	1.04	7.29	1.21
7	6.26	0.06	9.81	71.20	11.83	0.52	0.01	0.81	5.89	0.98
8	6.32	0.01	9.67	71.31	11.85	0.78	0.00	1.19	8.77	1.46
9	6.77	0.00	9.32	71.21	11.86	0.87	0.00	1.19	9.11	1.52
10	5.45	0.03	9.53	72.20	11.94	0.77	0.01	1.35	10.20	1.69
11	6.54	0.01	9.96	70.86	11.79	0.79	0.00	1.20	8.52	1.42
12	6.47	0.01	9.82	71.05	11.82	0.80	0.00	1.22	8.82	1.47
13	6.80	0.02	9.19	71.29	11.86	0.79	0.00	1.07	8.29	1.38
14	6.19	0.01	10.05	71.11	11.81	0.80	0.00	1.29	9.12	1.52
15	6.42	0.01	10.08	70.87	11.79	0.76	0.00	1.20	8.43	1.40
16	6.90	0.00	9.68	70.79	11.78	0.77	0.00	1.09	7.93	1.32
17	5.85	0.02	9.79	71.62	11.88	0.80	0.00	1.33	9.77	1.62
18	6.24	0.01	10.30	70.83	11.78	0.79	0.00	1.31	9.00	1.50
19	6.26	0.03	10.24	70.85	11.78	0.74	0.00	1.21	8.34	1.39

CO_2 – carbon dioxide – oxid uhličitý
SO_2 – sulfur dioxide – oxid siřičitý
H_2O – water – voda
N_2 – nitrogen – dusík
O_2 – oxygen – kyslík
v_{CO2} – volume amount of CO_2 – objemové množství CO_2
v_{SO2} – volume amount of SO_2 – objemové množství SO_2
v_{H2O} – volume amount of H_2O – objemové množství H_2O
v_{N2} – volume amount of N_2 – objemové množství N_2
v_{O2} – volume amount of O_2 – objemové množství O_2

(1) Číslo vzorku, (2) složky spalin, (3) objemová koncentrace složek spalin ve vlhkých spalinách, (4) objemové množství složek spalin

– cereal straw (pellets);
– meat and bone meal (pellets);
– mustard straw (pellets);
– Ekobiopal (pellets);
– cereal cleaning residues (pellets);
– meat and bone meal and energy sorrel in ratio 1:1 (pellets).

Pellets from fermented waste treatment mud with biomass with water content of 6.39 % vol. had relatively low heat parameters in comparison with other samples. The mixture of fermented waste treatment mud and hay in 1:1 ratio is not recommended for further use, because of its low heating power and large amounts of ash matter. Good parameters were reached by the sample of fermented waste treatment mud and energy sorrel.

It is necessary to obtain ideal burning conditions during combustion process to use the agricultural waste as alternative fuels in combustion equipments. Combusting of energy plants is not effective if these conditions are not satisfied. Therefore it is necessary to burn just the fuels specified by structure, sort, and quality. It is also necessary to pay permanent attention to these aspects.

In a long time perspective of sustainable development, it is very important to make use of such energy sources as effectively as possible. Also the use of financial sources should be, of course, optimized in order to limit – if it is possible, harmful effects on human health and environment. It also works for creating surplus for all parts of the world population.

In a medium time perspective, the greenhouse gas emissions, produced by human activities, influence climatic changes. These changes should be determined by a suitable method. There still exists also the impact of short time effects e.g. upon protection of energy supply.

One of the possibilities to prevent air pollution is the use of solid recovered fuels. Solid recovered fuels are the fuels prepared from the safe wastes sources. These are used to recuperate energy from the wastes by burning or common burning regulated by the legislation of common environment.

Solid recovered fuels start to play an important role in EU common energy policy. Costs and benefits analysis has shown that the use of solid recovered fuels contributes to reduction of greenhouse gases emissions. The using of solid recovered fuels might be especially important in the areas with the sparse population. It also works as the instrument to achieve the goals required by the direction on land fills by reduction of biodegradable wastes amount.

Solid recovered fuels might replace fossil fuels and to limit the wastes volumes deposited in land fills. This leads to improvement of effectiveness of fuel sources. If they are biomass based, their use is going to limit fossil carbon emissions to the atmosphere and to reduce the amount of greenhouse gases produced by anthropogenic activities. The solid recovered fuels based on biomass are the sources of storable solar energy.

Support of agricultural non-food production for its use as a renewable energy source is considered to be perspective not only from the aspects of ecology. Biofuels are not able to compete with classical energy sources (solid fuels, etc.) without the mentioned support. The current agrarian policy of EU, thereby also of the Czech Republic, accentuates such use of agricultural production as the most significant alternative towards the EU agricultural production restrictions. The state support is necessary in order the solid recovered fuels could gain a larger share on the market.

CONCLUSION

Results of measurements indicate the following conclusions:

– The most limiting factor for the heat use of the tested agricultural wastes is water and ash matter content. This statement has been proved by measurements.
– The alternative fuel composed of mixture of fermented sewage disposal plant sediments and hay in 1:1 ratio is not suitable because of its heat parameters.
– The sample of meat bone and meal has a higher content of sulphur and chlorine. It results in increase of emission concentrations. Sulphur emissions of the other tested samples are not a problem, as to the trace amounts.

- The solution leads to emission reduction and in this way also to reduction of environmental pollution.
- Definition of typical physical-chemical properties of selected agricultural wastes can be used as the initial data for material and thermal-chemical use.
- Determination of limiting factors for thermal use of selected agricultural wastes lead to their clear specification and classification.
- Fuel – wastes classification and specification will simplify the acceptability on the fuel market and the increase in public trust.
- Compilation of basic data for the agricultural wastes standardization and normalization such as energy sources and products for technical processing.
- The definite determination of typical physical-chemical properties is necessary for designing, building and checking of combusting equipments and for the thermal use of agricultural wastes. Burning of agricultural wastes is useless without meeting these premises.

This article was financially supported by the grant no. 31170/1312/313132 *Energetic utilization of solid and liquid biomass* and grant no. 31170/1312/313133 *Technical and economical appraisal of competitiveness of standardized biofuels in comparison to classical fuels and environmental impact assessment* – CIGA CUA Prague.

Received: 24 March 2006

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SOUHRN

Článek posuzuje možnosti tepelného využití vybraných odpadů ze zemědělské činnosti pro výrobu energie. Jedná se o možnosti využití odpadů, pevné biomasy, alternativních a standardizovaných paliv jako paliva pro tepelně energetická zařízení. V rámci výzkumného projektu je uskutečněno sedmnáct analýz na vybraných směsných odpadech ze zemědělské činnosti. Odpady převážně ve formě peletek jsou podrobeny rozboru, přičemž je zjištěno složení z hlediska stechiometrické a energetické bilance. Směsná peletovaná paliva z odpadů při zemědělské činnosti vykazují rozdílné tepelně-emisní parametry. To je způsobeno rozdílnými koncentracemi jednotlivých prvkových složení ve směsných odpadech.

U vybraných odpadů byl jednak stanoven prvkový rozbor na základní parametry paliv a stanovena stechiometrie základních ukazatelů, jako je výhřevnost paliva, množství kyslíku (vzduchu) potřebného k dokonalému spalování paliva, množství a složení spalin a měrná hmotnost spalin.

Z výsledků prvkových rozborů a stechiometrických výpočtů vyplývají některé negativní vlastnosti obsahu vody a popelovin v posuzovaných odpadech. Z ověřovaných vzorků odpadů ze zemědělské činnosti dosahovala lepších tepelných parametrů následující: sláma obilní a energetický šťovík v poměru 1:1 (pelety), sláma obilní a chrastice rákosovitá v poměru 1:1 (pelety), kakaové slupky, pelety z obilné slámy, masokostní moučka (pelety), sláma hořčice (pelety), ekobiopal (pelety), zbytky po čištění obilí (pelety) a nakonec masokostní moučka s energetickým šťovíkem v poměru 1:1 (pelety).

Peletky z fermentovaných čistírenských kalů s biomasou o obsahu vody 6,39 % hm. dosahovaly oproti ostatním vzorkům dost nízkých tepelných parametrů. Jako alternativní palivo ze směsi fermentovaných čistírenských kalů a lučního sena v poměru 1:1 není doporučeno (vzhledem k nízké výhřevnosti a velkému množství popele) pro jeho další tepelné použití. Dobrých tepelných parametrů dosahoval vzorek fermentovaných čistírenských kalů s energetickým šťovíkem.

Nejvíce určující z hlediska emisních koncentrací je množství síry, dusíku a chlóru v odpadech. Emise síry u tepelných zařízení na biomasu nepředstavují (co se týče limitních hodnot) normálně žádný problém. U směsných odpadů s rostlinou biomasou je patrný vysoký nárůst emisí dusíku, jelikož energetické rostliny vykazují vyšší hodnoty dusíku v palivu.

Řešená problematika přispívá svojí aktuálností k omezování emisí a tím ke snížení úrovně znečišťování ovzduší.

Klíčová slova: biomasa, alternativní paliva, odpady ze zemědělství, elementární analýza, stechiometrické výpočty