Physical and chemical properties of fuel containing animal waste

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Abstract

The paper includes the results of research devoted to the application of meat and bone meal (MBM) as a component of granulated alternative fuel for use in the cement industry. This paper presents the composition of the fuel along with the method of its production. The paper later undertakes an analysis of chemical and physical characteristics of the resulting fuel with a particular emphasis on the combustion properties, content of noxious substances and strength prosperities.
Keywords: animal by-products, meat and bone meal, alternative fuels, cement industry.

1 Introduction

Animal by-products generated by the food industry require the application of special treatment techniques due to the hazard they pose to the environment. Because of bacteriological hazard, the intensive, foul smell and difficulties in storing, it is necessary to ensure its fast utilization.

In the utilization plants the animal by-products undergo the processes of grinding, drying, sterilization and degreasing, which result in the formation of animal meal and fats.

In Poland the total mass of 685,000 tons of animal waste undergoes utilization; however, forecasts say that the volume may reach 770,000 tons within the next 5 to 7 years [1].

The quantity of the generated animal by-products in the selected European states is presented in Fig. 1.

Depending on the type of the utilized waste, it gives origin to a variety of animal meals: bone meal, meat meal, bone and meat meal, poultry meal and fish meal.

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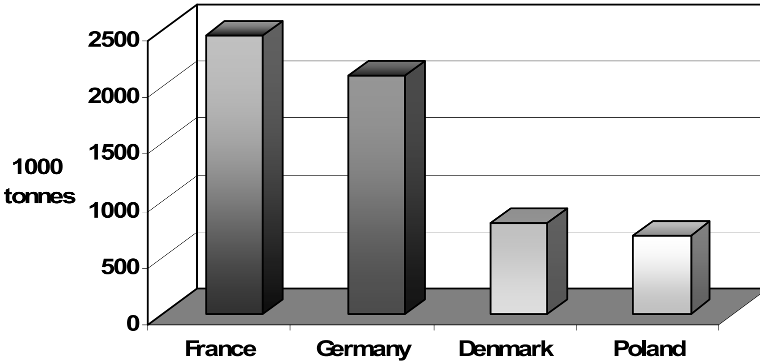

Figure 1: Production of animal by-products in selected European countries [1].

The data collected in [1] indicates that the output of utilization plants in Poland amounts to around 250 kg of meal and 100 kg of fat out of each ton of animal waste.

Until now the meat and bone meal (MBM) was mainly applied as a component of feed for farm animals. However, in connection with the the threat resulting from the spread of BSE disease and the probability of its effect on humans, the application of meals in feeding farm animals was subjected to strict formal control [2].

Nowadays, one disposal option is combustion or the co-combustion of MBM with coal, which ensures that any living organism is totally destroyed and at the same time valorizing its energetic potential [3–6]. The properties which promote the combustion of MBM in industrial processes include the low moisture content, the high calorific value which is similar to the calorific value of low quality hard coal and sulfur content lower than for the case of a majority of brown coal sorts.

However, such factors as the MBM tendency towards displaying powdery characteristics, biological activity and considerable fat content account for the limitations in the application of the meal in the existing installations. Biological activity which is revealed in the conditions of high moisture content can be demonstrated in the processes of decay and hence is associated with a health threat to the personnel involved.

Technical problems are associated with the tendency of MBM to form powder and the grease contained in the meal, which results in clogging of the transportation pipes.

The variable moisture and fat content in meals and changeable chemical composition result in the necessity of applying specific solutions with regard to combustion conditions and transportation.

This paper includes a presentation of a technique of MBM application to form granulated fuel, which may secure an alternative of an installation in which the input of meal in its powder form may be inadvisable.

2 Materials and methods

As a result of the huge demand for supplementary sources of energy in the form of supplementary fuels, a new fuel designated for application in the process of cement clinker-burning resulted from this research.

This fuel applies MBM along with sewage sludge from a municipal waste treatment plant. The application of the other component of the fuel results from the physical properties of the sludge. Since the sewage sludge has the high moisture content, its combination with MBM results in a mixture with humidity content in the range of 40 per cent, which enables its formation into granulate. The properties of the components of the fuel are summarized in Table 1.

Table 1: Characteristics of components.

Parameter	Unit	MBM	Sewage sludge
Physical form		Grounding ≥4 mm	Pasty consistence
LHV	MJ/kg	17.45	10.73*
HHV	MJ/kg	19.18	11.62*
Moisture	%	5.31	71.20
Volatile matter	%	65.21	49.33*
Ash	%	20.46	35.61*

* In dry mass.

The fuel formation was possible in a specially designed drum granulator designed for formation of fuels from waste. The drum is equipped with a special batching system which results in gaining the granulate diameter in the range from 15 to 35 mm [7].

The method of fuel production consists in the initial mixing of the components at fixed ratios and the subsequent granulation and drying in the drum granulator.

The fuel based on bone and meat meal and sewage sludge was named PBM fuel. The PBM fuel was subsequently subjected to testing aimed at the determination of the energy and physical properties, including:

a) heating value using Oxygen Bomb Calorimeter KL- Mn,
b) elementary analysis with Elementar Analyzer Vario Macro EL,
c) heavy metals content with ICP MS Perkin Elmer Elan 6100 Mass Spectrometer,
d) chemical composition of ash with Atomic Absorption Spectrometry ASA method,
e) polychlorinated biphenyles (PCBs) with Agilent 6890N gas chromatograph with ECD detector,
f) strength drop in accordance with ISO 616: 1995(E) standard,
g) bulk density in accordance with PN-ISO567 standard.

3 Results and discussion

The application of alternative fuel in the process of cement clinker-burning is subjected to numerous technical and technology related restrictions. This results from the fact that the fuel supplement with waste must not have a negative effect on the process of clinker production in the kiln and consequently on the quality of the cement and the emission levels.

In connection with the above the alternative fuels used in cement clinker-burning are required to conform to the required physical and chemical properties. The properties of the fuel derived from meat and bone meal and sewage sludge was compared with the requirements specified by the cement industry concerning alternative fuels.

The most comprehensible effect on the applicability of the fuel based on waste is associated with its calorific value and chemical composition. The energy properties of PBM fuel are summarized in Table 2.

Table 2: Energy properties of PBM fuel in comparison to cement industry requirements.

Parameter	Unit	PBM fuel	Requirements specified by cement industry [8, 9]
LHV	MJ/kg	13.55	>13
HHV	MJ/kg	15. 53	-
Moisture	%	8.67	<30
Volatile matter	%	51.92	-
Ash	%	30.80	< 40
Elementary composition			
Carbon C	%	33.47	
Hydrogen H	%	3.77	
Oxygen O and Nitrogen N	%	22.67	
Sulphur S	%	0.62	<2.5
Chlorine Cl	%	0.040	<0.3

The analysis of the energy parameters of PBM fuel leads to the conclusion that the properties of the fuel fulfill the minimum heat value. Hence, it is possible to substitute alternative with the PBM fuel in 10 percent of the total volume of fuel use. The greater content of an application of PBS fuel may result in a decrease in the kiln effectiveness and increase of the heat used in the process.

PBM fuel contains a considerable amount of ash. However, one has to bear in mind that the ash resulting from the combustion process is absorbed by the clinker and hence it is necessary to take into consideration its chemical composition while deciding about the input of the raw materials in order not to disturb the relations between the constituents forming the material used for preparation of rawmix.

With regard to emissions the components which are undesirable include sulfur, chlorine, volatile heavy metals (Hg, Cd and Tl) and polychlorinated biphenyls (PCBs), hence, restrictions on their content in alternative fuels have been imposed. The content of the components in the resulting PBM fuel is considerably lower than the admissible levels (Table 1 and Table 2).

Simultaneously, the detrimental effect on clinker quality may be associated with heavy metals content in ash in the structure of the resulting cement. They are combined into the structure of cement as a result of very durable chemical processes, which may affect clinker structure and hence lead to the deterioration of cement quality.

The references used here list information concerning the negative impact of the elementary composition (including Pb, Cb, Zn, Cr, Ni, As, Ag and Ba) on the quality of Portland cement [10,11,12]. The content of heavy metals in the gained PBM fuel is summarized in Table 3.

Table 3: Hazardous material content in the PBM fuel in comparison to technological restriction imposed of cement industry.

Parameter	Unit	PBM fuel	Requirements specified by cement industry [8, 9]
Heavy metals			total content < 2,500
Pb		19.43	
Zn		446.1	
Sn		0.0304	
Cr	ppm	22.08	
Fe		2030	
Cu		43.84	
Ni		4.92	
Cd		0.434	Cd+Tl+Hg < 100
Tl		0.051	
Hg		0.421	< 10
PCB	ppm	< 0.05	< 50

The following Table 4. illustrates the chemical composition of PBM fuel ash in comparison to the composition of clinker and hard coal ash. The main oxides included in PBM fuel ash there are CaO, SiO_2, Fe_2O_3 and Al_2O_3, the list of which is the same as in the raw materials used for clinker production. However, the high content of P_2O_5 is not beneficial since it affects the hydraulic activity of cement.

The content of P_2O_5 in clinker must not exceed 0.2-0.3%, hence in the application in PBM fuel it is necessary to pay attention to quantity of batched fuel which beside must conform the requirements concerning calorific value and must not display undesired properties.

The experience gained in the cement industry leads to the conclusion that the 20 percent P_2O_5 content in the meal will render it possible to use it for kiln entry in the quantity, which corresponds to 5 percent of heat demand [9].

Table 4: Chemical composition of PBM fuel in comparison to the components of clinker and hard coal ash.

Compound % of mass	PBM ash	Hard coal ash [13]	Blast furnace slag	Lime stone*	Siderite*
SiO_2	17.88	42.00	0.70	7.20	32.20
Al_2O_3	4.04	20.00	38.10	2.40	12.20
Fe_2O_3	7.08	17.00	6.90	1.10	27.60
CaO	42.35	5.50	42.50	48.60	2.60
MgO	0.95	2.10	7.10	0.40	2.40
P_2O_5	21.06	-	-	1.5	-
TiO_2	0.36	1.20	-	-	-
SO_3	0.50	5.00	-	0.60	3.20
Compounds not marked	5.78	7.20	4.7	0.50	0.70

* The remainder is ignition loss (it is not marked in table).

Apart from the chemical properties of the fuel must fulfill the requirements ensuring stability, homogeneity of the composition and physical properties.

Some of the other properties, which are particularly relevant for the cement industry, include the ones which promote its transport, storage and batching.

The examinations conducted on the PBM fuel confirm the applicability of the granulated form for application in the kiln.

The PBM fuel with 35 mm granulation is shown in Fig.2 and the bulk density is given in Table 5.

Figure 2: PBM fuel.

Table 5: Bulk density of PBM fuel.

Parameter	Unit	Granulation 25 mm	Granulation 35 mm
Bulk density	kg/m^3	310	325

Stability of the fuel form is extremely important during its transport and storage. This parameter can be assessed by marking its drop strength.

This test determines the changes in the structure of fuel when it is dropped from a height of 1.5 m on a concrete foundation under standardized conditions.

When fuel is stored, it is often influenced by unfavourable atmospheric conditions, which may negatively affect fuel-hardness. This may be mostly influenced by the change in fuel-moisture as a result of its moisture absorption from surroundings and precipitation. Therefore, its water resistances is still another appointed parameter, which is defined as a degree of the change in the drop strength of fuel formed as a result of water absorption.

PBM fuel was subsequently subjected to the testing of its resistance to frost. The fuel was subjected to 50 cycles of frosting and defrosting. Each cycle involved freezing the fuel to -18^{o}C, and subsequent defrosting till 18^{o}C. Following that the resistance of the fuel to drop was tested. The results of researches are presented in Fig.3.

The analysis of the results of fuel drop strength confirms that it fully fulfills the necessary strength properties.

On the basis of the conducted research an observation was made that water has a destructive effect on the strength of the fuel. It was found that after the fuel absorbs water its strength tends to drop dramatically. At the same time, the examination of fuel resistance to frost leads to the conclusion that the strength of the fuel after the test fell only by 8%.

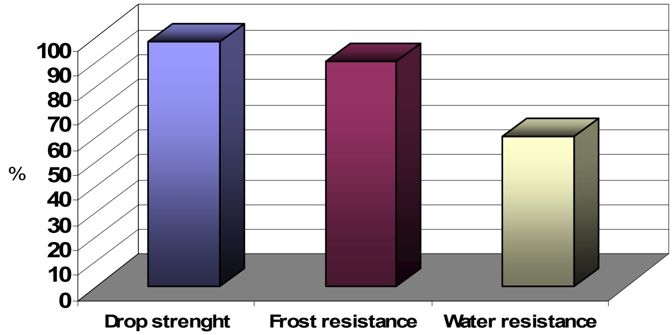

Figure 3: Physical properties of PBM fuel.

The conclusion of the following is that the fuel should be stored in the area protected from rainfall.

4 Conclusions

The conducted examinations and analysis leads to the following practical conclusions:

– The application of meat and bone meal as component of granulated fuel may be an alternative for the installation in which the input of powder animal meal may be undesirable.

– The combined use of meat and bone meal and sewage sludge enables the full application of its energy potential.
– PBM fuel displays properties which fulfill the requirements specified by cement industry and may be applied as the substitute of coal in the process of clinker cement-burning.
– The only problem may be associated with the high content of P_2O_5 in fuel ash, which must be taken into consideration in the determination of maximum P_2O_5 content in the resulting clinker not exceeding the admissible level.
– The properties associated with high water absorption result in the deterioration of the mechanical properties of the fuel. For that reason the fuel should be ensured dry storage facilities.
– The produced fuel can be introduced into the chamber located between the cyclone preheater and the rotary kiln or into the precalciner burner installed in the state-of-the art in modern kiln installations. Those are the places where the kiln can be charged with low- energy fuels showing a high moisture content and likely to contain a larger amount of mineral matter.
– The physical composition and form of the produced PBM fuel makes it possible to be used in other processes of industrial fuel combustion, e.g., in the process of co-combustion with coal in the existing power plants and heat generating plants.

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