ANALYSIS OF USABILITY OF SHELLS FROM PROCESSING OF PALM NUTS TO PALM OIL AS SOLID FUEL

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Abstract. The paper describes an attempt to analyze the usability of shells from palm oil nuts as a future ecological solid fuel. The analysis of shells from palm nuts processing comprised the following aspects: analysis of possible utilization of palm shells as a substitution for pellets, processing of palm shells to pellets and briquettes, assessing of the calorific value and moisture content of palm shells, assessing of the mechanical properties such as mechanical durability of the pellets made of palm shells, assessing of emission release during the burning process of palm shells. The performed examination of the calorific value, the heat combustion, the ash content, the moisture content of the palm shells, as well as examination of the briquettes making process from palm shells gives the opportunity to make a conclusion, that solid biofuel made of the palm shells, in comparison to other types of biomass, could be a very promising type of alternative fuel. And because it is a waste material from one of the most important oil plants, it is produced in high amounts of this material, it could be successfully used by the commercial companies as a source for small, medium and large scale energy installations.

Keywords: oil palm, palm shells, solid fuel, pellets, briquettes.

Introduction

Past several years there was observed the increase of the demand for solid biofuels such as pellets and briquettes. In the Czech Republic there was registered annual growth of consumption of pellets and briquettes more than 30 % between the years 2005 and 2010. According to increasing sales of boilers for biomass combustion there is expectation of continuing of growing consumption of solid biofuels. Producers of pellets and briquettes are faced with many problems, there is huge growth of consumption of pellets and briquettes, on the other hand, there is a lack of input material such as sawdust and wood shavings and disproportionate increase in the price of this input material [1].

1. Briquette and pellet production from waste material

An interesting way of using biomass (including waste biomass) for energy purposes is producing solid biofuels through agglomeration (production of pellets and briquettes).

Production of pellets and briquettes is a process of compacting loose material to a form compressed and homogenous product.

Briquettes are made from dry wood dust, pulp, sawdust, bark, wood shavings or plant pulp in the form of cylinders, prisms or hexahedrons, with a diameter of 40 – 100 mm and length 300 mm. According to the selected type of the material, on the market there can be found briquettes from wood, bark, straw, energy crops, and briquettes made of mixtures of these materials – the so-called mixed briquettes [2].

Pellets are highly compressed cylindrical moldings, mostly manufactured in 6 mm diameter and length varied from 5 to 40 mm. Pellets are made of wood residues, usually from sawdust and shavings. In addition to these wood pellets appeared also on the market pellet as plant, bark, peat pellets and other biomass materials and their inter-mixtures – the so-called mixed pellets [3].

The processed biomass to the form of pellets and briquettes gets an added value and enables its better transportation, storage and reduced volume.

There were many studies done [4 – 6] about the factors which have influence of the agglomeration process and the quality of products (pellets and briquettes). These factors can be divided into the following groups:

- chemical and biological factors – chemical composition and biological structure;
- pretreatment and material factors – preparation of material for processing (moisture of feedstock, temperature of feedstock, granulometric composition of feedstock);
- equipment factors – construction of processing equipment;

- process factors – factors related with processing (condensing pressure, temperature of processing, speed of processing, etc.).

2. The research problem

One of the possible types of waste biomass, which is possible to be used as solid biofuel, are palm shells. Palm shells are a by-product during processing of the oil palm fruits to palm oil. Currently palm shells are co-firing with coal in thermal power plants to produce electricity and heat. Another possible utilization of palm shells is for production of standard solid biofuels (pellets and briquettes) made of pure material, mixture of the shells and another biowaste, and utilization of pure shells with some modifications for direct combustion as a substitute for pellets.

Waste material from palm oil production such as palm shells is produced in huge amounts with little utilization. In general, a fresh fruit bunch contains (by weight) about 21 % palm oil, 6 – 7 % palm kernel, 14 – 15 % fiber, 6 – 7 % shells and 23 % empty fruit bunches [7]. According to FAO the world production of palm oil was 45 million t in 2009 [8]. The estimated world production of palm shells is 10 million tons per year.

The main aim of the research is to analyze the possibility of production of standard biofuels (pellets and briquettes) made of pure shells, mixture of shells with another biowaste material and utilization of palm shells for direct combustion with some modifications as a substitute for pellets.

Materials and methods

In the research there are the following characteristics of palm shells determined:

1. Energetic properties (calorific value, heating value, ash content and moisture content)
2. Mechanical durability of briquettes made of mixture of palm shells and wood shavings
3. Emission from combusting of palm shells.

1. Research material

The palm shells were obtained from the BOR Technology Ltd., this company is evolved in solid biofuel business and has intents to import palm shells for large scale energy installation for co-firing with coal in thermal power plants.

2. Determining the energetic properties, ash content and moisture content of palm shells and particle size analysis

Determination of the energetic values of palm shells contains the following steps: determination of the moisture content, heat of combustion, calorific value and ash content of palm shells.

The moisture content was determined in a heating oven Memmert model 100 – 800 according to the standard: ČSN P CEN/TS 14774-1 (-2,-3), and standard formula was used (1)

$$w = [(m_w - m_d)/ m_w] \cdot 100 \tag{1}$$

where w – moisture content, %;
m_w – total mass of wet material, g;
m_d – DM mass of dried material, g.

To determine the calorific value and heat of combustion the sample was dried at 105 ºC and subsequently the calorific value and heat of combustion were determined in the dry matter using an automatic adiabatic combustion calorimeter Laget MS 10 A. In the calorimetric vessel the sample is totally burned and the values of temperature jumps were converted to the recommended standards (ČSN EN 441352) on the net energy value.

Determination of ash in the sample is carried out according to CEN / TS 14775. The ash content is determined by the weight of the residue that remains after gradual heating of the sample in the air temperature (550 ± 10) ºC. The determination is carried out in a muffle furnace for one sample and repeated three times.

For particle size analysis 2 mm, 3.15 mm, 5 mm, 10 mm and 15 mm sieves were used. The sieves were put in the vibrating pad and vibrating was stopped till the weights of all sieves were not changing.

3. Pelletizing and briquetting of palm shells

For production of pellets pelletizing line MGL 200 made by the company Kovo Novak Ltd. was used. The pelletizing line was equipped by a matrix of 8 mm. The material for pelletizing was ground in the Hammer mill. A sieve of 3.8 mm in diameter was used. The ground material was used for production of pellets – pure and mixed with sawdust in ratio 1:1 by weight.

For production of briquettes the briquetting machine BrikStar model 50-12 made by the company Briklis Ltd. was used. The material for briquetting was divided in 3 parts, one part was ground in the hammer mill with using a sieve of 3.8 mm in diameter, the second part was ground with using a sieve of 8 mm in diameter and the third was used untreated. All parts were mixed with wood shavings in ratio 1:1 by weight. There was also one attempt made to use untreated material without mixing with wood shaves.

4. Determining the mechanical durability of briquettes made of mixture of palm shells and wood shavings

The mechanical durability was determined according to CEN/TS 15210-2. The samples of briquettes are placed into the test drum (Figure 1) equipped with a baffle. When rotating the drum, the briquettes crack each other and to the walls. The whole particles are weighed and abrasion of small particles is determined.

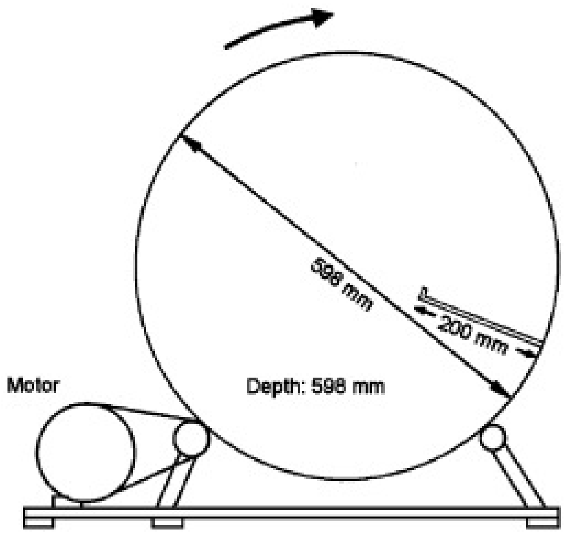

Fig. 1 **Briquette durability tester**

5. Determining the emission of palm shells

Emission of palm shells was tested in a stove for standard pellets made by the company Kovo Novák model KNP 5, the rated capacity of the stove is 18 kW. Treatment of shells includes only a sieve 15 mm to remove the particles bigger than 15 mm to ensure proper operation of the screw conveyor.

As a reference fuel standard 6 mm wood pellets were used, burning took place under the same conditions, the same speed screw conveyor and the same size of the air inlet. For emission analysis the versatile exhaust gas system Testo 350 XL was used. The Testo 350 XL flue gas analyser is equipped with gas sensors for O_2, CO, NO, NO_2.

Results and discussion

1. *Energetic properties, moisture content and ash content of palm shells*

The research carried out indicates that palm shells are a material of very low humidity which reaches 7.46 % and because of the residual oil content they do not tend to water intake. Such amount of humidity is good for direct combustion and for further processing of palm shells for production of standard solid biofuels (pellets and briquettes) made of pure material or mixture with other biomass.

Table 1 presents the results of the water content, ash content, heat of combustion, calorific value and loose density.

The calorific value and heat of combustion achieve high values compared to briquettes which achieve the calorific value about 12 – 16 MJ·kg^{-1} [9] and pellets about 16 – 18 MJ·kg^{-1} [3].

Table 1

Energetic properties of palm shells

Water content, %	Ash content, %	Heat of combustion, MJ·kg^{-1}	Calorific value, MJ·kg^{-1}	Loose density, kg·m^{-3}
7.46	3.22	22.14	19.61	608

2. *Mechanical durability of briquettes*

The first experiment with palm shells was done with pure samples of palm shells, in case of production of briquettes untreated palm shells were used and in case of pellets the production material was ground to the maximum size of particles 3.8 mm. The results showed that the material could not join together; this is due to low content of lignin.

The second experiment for production of briquettes was done with a mixture of palm shells and wood shavings. The palm shells were ground to the maximum particle size 3.8 mm and 8 mm, one sample was not ground. The resulting briquettes were of very poor quality and after the mechanical durability test was done, the samples with ground palm shells disintegrated at 100 % and the sample which was not ground disintegrate at 60 %. For future analysis it is recommended using a higher ratio between palm shells and wood shavings in behalf of wood shavings or using material with high content of lignin (for example *cannabis sativa*).

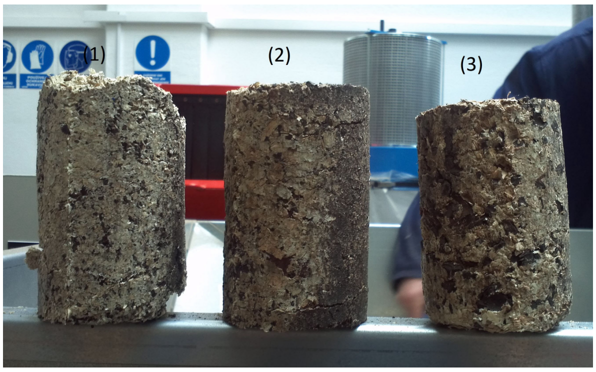

Fig. 2. **Samples of briquettes made of mixture of palm shells and wood shavings in ratio 1:1 by weight:** 1 – palm shells ground to 3.8 mm; 2 – palm shells ground to 8 mm; 3 – not ground palm shells

3. *Emission of palm shells*

The results of determining the emissions of CO, CO_2, NO, NO_2 of palm shells are presented in Table 2 and in Figure 3.

As it can be seen in Figure 1 the comparison with wood pellets shows that the emissions of CO and CO_2 of palm shells are little bit lower than the emissions from wood pellets, but the emissions of NO and NO_2 are much higher, this is due to the presence of residual oil. Emission limits for boilers up to 0.2 MW are not established in the Czech Republic.

Table 2

Comparison of emissions from combustion of wood pellets and palm shells

Emissions	Palm shells	Wood pellets
CO, $mg \cdot m^{-3}$	475.42	488.38
CO_2, $mg \cdot m^{-3}$	7.73	9.76
NO, $mg \cdot m^{-3}$	109.20	61.35
NO_2, $mg \cdot m^{-3}$	0.56	0.28

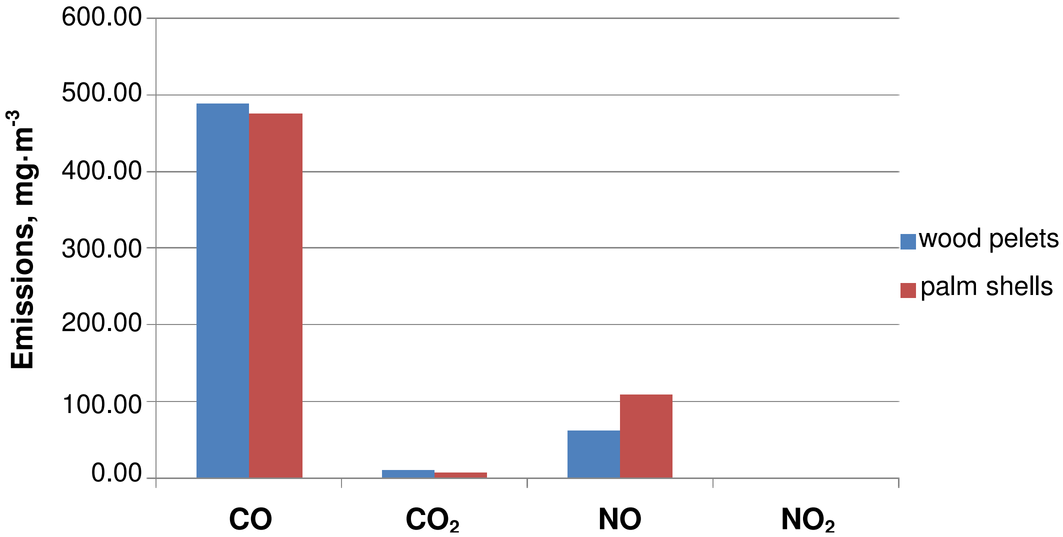

Fig. 3. **Comparison of emissions from combustion of wood pellets and palm shells**

4. Possibility of use of palm shells as a substitute for pellets

An interesting way how to use palm shells is using it as substitution for pellets, not treated or with simple treatment – to remove big particles to ensure proper functioning of the screw conveyor. This depends on the technical specification of individual manufacturers of boilers. The results of testing in the boiler Kovo Novák KNP 5 show that the screw conveyor is not able to work with particles bigger than 15 mm, which is only 0.3 % (Table 3 shows the particle size analysis), when these particles were removed the boiler was able to work continuously (8 hours test was performed)..

Table 3

Particle size analysis

Diameter of sieves, mm	Percentage distribution of fractions, %
15.00	0.3
10.00	7.9
5.00	70.3
3.15	16.5
2.00	3.8
0.00	1.3

Conclusions

The performed determination of the energy properties shows that palm shells reach very high values, the heat of combustion is 22.14 $MJ \cdot kg^{-1}$ and the calorific value is 19.61 $MJ \cdot kg^{-1}$. These numbers are much higher than wood pellets and briquettes are able to reach. Palm shells have also very low water content, only 7.46 % and because of the residual oil content do not tend to water intake.

On the other hand, palm shells have a low content of lignin and it prevents production of standard biofuell (pellets and briquettes) made only with pure material. The only possibility for production of standard biofuels seems to make it as a mixture of biomaterials with high content of lignin; future study needs to be done.

The emission analysis shows that the emissions of CO and CO_2 of palm shells are little bit lower than the emissions form wood pellets, but the emissions of NO and NO_2 are much higher, this is due to the presence of residual oil. Emission limits for boilers up to 0,2MW are not established in the Czech Republic.

The analysis shows that the best possible way how to use palm shells for energetic purposes is to use them as a substitute for pellets. The performed analysis shows that it is possible to use palm shells in boilers designed for burning pellets only with small treatment – removing particles bigger than 15 mm to ensure proper functioning of the screw conveyor.

The research allows affirming that palm shells could be used as a substitute for pellets. In the less developed countries there is a large production with little utilization. The study shows that palm shells could be a very promising type of alternative fuel and, because it is a waste material from one of the most important oil plants, the production of this material is high.

References

1. Bufka A., Briquettes and pellets in 2010. TZBinfo.cz. [online] [14.11.2011]. Available at: http://oze.tzb-info.cz/biomasa/8030-brikety-a-pelety-v-roce-2010
2. Stupavsky V, Holy T. Brikety z biomasy - dřevěné, rostlinné, směsné brikety. Biom.cz [online]. [1.1.2010]. Available at: http://biom.cz/cz/odborne-clanky/brikety-z-biomasy-drevene-rostlinne-smesne-brikety. ISSN: 1801-2655.
3. Stupavsky, V. Pelety z biomasy - dřevěné, rostlinné, kůrové pelety. Biom.cz [online]. [1.1. 2011]. Available at: http://biom.cz/cz/odborne-clanky/pelety-z-biomasy-drevene-rostlinne-kurove-pelety. ISSN: 1801-2655
4. El, Nasir. Handbook of bioenergy crops: a complete reference to species, development and applications. Earthscan James & James, 2010. Print. ISBN: 978-1-84407-854-7
5. Rosillo F. Groot P., Hemstock S. L., and Woods J. The biomass assessment handbook: bioenergy for a sustainable environment. Earthscan James & James, 2007. Print. ISBN-10: 1-84407-285-1
6. Obidziński, S. Analysis of usability of potato pulp as solid fuel. Fuel Processing Technology. Volume 94, Issue 1, February 2012, Pages 67-74. ISSN: 03783820
7. Husain Z., Zainac Z., Abdullah Z.: Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Biomass and Bioenergy 22 (2002). 505–509p. ISSN: 09619534
8. FAOSTAT. 2009. [online][8.3.2012] Available at: faostat.fao.org
9. Stupavský, V., Holý, T.: Brikety z biomasy - dřevěné, rostlinné, směsné brikety. Biom.cz [online] [1.1.2010]. Available at: http://biom.cz/cz/odborne-clanky/brikety-z-biomasy-drevene-rostlinne-smesne-brikety ISSN: 1801-2655