UTILIZATION OF *JATROPHA CURCAS* L. SEED CAKE FOR PRODUCTION OF SOLID BIOFUELS

Michal Kavalek[1], Bohumil Havrland[1], Tatiana Ivanova[1], Petr Hutla[2], Pavel Skopec[3]
[1]Czech University of Life Sciences Prague; [2]Research Institute of Agricultural Engineering, Czech Republic; [3]Czech Technical University in Prague
kavalek@its.czu.cz

Abstract. This paper describes an attempt to analyze the usability of *Jatropha curcas* L. seed cake as a future ecological solid fuel. Jatropha is a unique and potential tropical plant and it is propagated for augmenting renewable energy sources due to its several ecological and environmental benefits. The plants are cultivated in extensive plantations on degraded wasteland throughout the world. The analysis of Jatropha seed cake comprised the following aspects: analysis of possible utilization of Jatropha cake as a substitution for standard woody pellets in domestic boilers, assessing of the physical and chemical properties. Analysis of possible utilization of Jatropha seed cake as a raw material for production of briquettes, assessing of the physical and chemical properties of briquettes, analysis of emissions and comparison with standard woody pellets. The performed physical and chemical examination of the Jatropha seed cake gives the opportunity to make a conclusion, that it, in comparison to standard woody pellets, reaches similar or better physical and chemical properties, it is also able to reach the European standard EN 14961-1 for solid biofuels.

Keywords: *Jatropha curcas* L., solid biofuel, emissions, combustion, seed cake.

1.1 Introduction

Jatropha curcas (*Jatropha curcas* L.) is a multipurpose tropical tree or large shrub with the origin in Latin America. It is widely cultivated in Latin America, Africa, India and South-East Asia. In India, Portuguese navigators introduced it in the 16th century. It occurs in almost all parts of India including Andaman Island and is generally grown as live fence. It is well adapted to arid and semiarid conditions [1].

It is a drought and pest-tolerant plant and unpalatable by animals. It is planted in tropical countries principally as a hedge, protecting cropland from the cattle, sheep and goats. *Jatropha* is currently popularized as future ecological energy plant, because of high contend of oil in the seeds which varies from 30-35 % and production of seeds varies from 0.5 to 12 ton per year from hectare depending on the soil, nutrient, rainfall conditions, and *Jatropha* variety [2; 3].

The jatropha industry is in its very early stages, covering a global area estimated at some 900,000 ha. More than 85 percent of jatropha plantings are in Asia, chiefly Myanmar, India, China and Indonesia. Africa accounts for around 12 percent or approximately 120,000 ha, mostly in Madagascar and Zambia, but also in Tanzania and Mozambique. Latin America has approximately 20,000 ha of jatropha, mostly in Brazil [4].

The area planted to jatropha is projected to grow to 4.72 million ha by 2010 and 12.8 million ha by 2015. By then, Indonesia is expected to be the largest producer in Asia with 5.2 million ha, Ghana and Madagascar together will have the largest area in Africa with 1.1 million ha, and Brazil is projected to be the largest producer in Latin America with 1.3 million ha [4].

1.2 The research problem

Ineterst in production of *Jatropha curcas* is groving in many countries, mainly for oil production. This interest is driven by the ability of *Jatropha* to grow on land which is marginal for agriculture production [5].

During seed processing to the oil there is generated waste production. With every tone of *Jatropha* oil there are produced aproximatelly 3 tons of waste material in the form of seed cake. Curently the most common seed cake utilization is as mulch in plantations of *Jatropha* [6]. An interesting posibility of utilization is to use *Jatropha curcas* seed cake for direct combustion as a pellet substitute in domestic boilers.

2. Materials and methods

In the research there are determined the following characteristics of *Jatropha curcas* L. seed cake:

1. Energetic properties (calorific value, heating value, ash content and moisture content)
2. Particle size distribution
3. Emission from combusting of Jatropha seed cake

2.1 Research material

Jatropha seed cakes were obtained from Farmet Inc. This company is involved in production of agriculture machinery and technology to process oil seeds crops.

2.2 Determining the energetic properties, ash content and moisture content of *Jatropha curcas* seed cake and particle size analysis

Determination of the energetic values of *Jatropha curcas* seed cake contains the following steps: Determination of the moisture content, heat of combustion, calorific value and ash content.

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

The calorific value was determined according to the standard EN 14918 as follows:

Gross calorific value

Gross calorific value is the amount of heat per unit of weight released by complete combustion of the fuel in the pressure vessel built in the calorimeter under compressed oxygen at 25ºC. It is Laget MS 10 A calorimeter according to the standards EN 14918. In the calorimetric vessel the sample is totally burned and the values of temperature jump were converted to the net energy value.

Net calorific value

Net calorific value is gross calorific value minus the heat of vaporization of water, resulting from the fuel during combustion.

The ash melting behavior was determined by use of the standard EN 15370–1. The ash was grinded down to maximum particle size less than 0.075 mm. A sufficient quantity of the prepared ash was moistened with demineralised water so that paste was made; it was pressed into the mould with pressure about 1.5 N mm^{-2}. The pieces prepared for testing were put into a furnace and dried at maximum temperature 150 ºC (below the expected shrinkage starting temperature). The allowed temperature rising gradient during the tests could be 3-10 ºC·min^{-1}. During the test a picture had to be taken at least every 10 ºC.

The bulk density was determined according to the standard EN 15103. For solid biofuel tests the maximum particle size up to 12 mm was used and the vessel had the dimensions: height: 228 mm and inner diameter: 167 mm. The sample was put into the vessel and dropped from 150 mm, this was repeated three times. After this the vessel was filled to the brim with the tested material and it was weighed.

Volatile matter was determined according to the standard EN 15148. The sample was combusted 7 minutes in anaerobic conditions in air temperature (900 ± 10 ºC). The content of volatile matter was expressed as percentage of weight loss from the sample.

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

2.3 Determining the emission of *Jatropha curcas* seed cake

The emissions were determined by a portable emission analyzer Testo 350 XL. Emissions from burning *Jatropha curcas* seed cake were tested in a boiler for standard pellet combustion made by the company Verner model A25, with fixed-bed combustion, rated capacity of the stove is 25 kW. *Jatropha curcas* seed cake was used untreated. As a reference fuel standard 6 mm wood pellets with known chemical and energetic properties were used. Emission of pellets and *Jatropha curcas* seed cake were measured at energy output 18.5 kW. There was set optimal air excess λ to 2 for each measurement. Two hours test for each fuel was performed.

For emission analysis a versatile exhaust gas system Testo 350 XL was used. The Testo 350 XL flue gas analyzer was equipped with gas sensors for O_2, CO_2, CO, NO, NO_2.

The result statistical analysis was carried out using Microsoft Excel 2007 and StatSoft Statistica 10. The analysis included a pair-wise F-test to assess when variance homogeneity could be assumed. Box plot was used to express the results.

3. Results and discussion

3.1 Energetic properties of pellet substitute based on *Jatropha curcas* seed cake

The energetic properties of the pellet substitute based on *Jatropha curcas* seed cake are characterized by the moisture content, volatile matter, ash content, bulk density gross calorific value, net calorific value and ash melting behavior described by deformation temperature, hemisphere temperature and flow temperature. All parameters are summarized in Table 1.

Table 1

Energetic properties of *Jatropha curcas* seed cake

Energetic properties	Unit	Value
Moisture content	% of weight	7.96
Volatile matter	% of weight	67.37
Ash content	% of weight	5.48
Bulk density	$kg \cdot m^{-3}$	670
Gross calorific value	$MJ \cdot kg^{-1}$	19.11
Net calorific value	$MJ \cdot kg^{-1}$	17.56
Ash melting behaviour	**Unit**	**Value**
Deformation temperature	ºC	1110
Hemisphere temperature	ºC	1130
Flow temperature	ºC	1145

The carried out research results indicate that the *Jatropha curcas* seed cake is a material of a very low moisture content (7.96 %), and the residual oil content does not tend to water intake. Such amount of humidity is good for direct combustion. The ash content reaches 5.48 % which is higher when compared to woody pellets (1.5 %), it is comparable to herbaceous biomass (3–10 %).

The oil *Jatropha curcas* seed cake bulk density reaches high values which encourages transportation and storage. Other parameters are similar values to woody biomass.

3.2 Particle size distribution

The analysis of particle size distribution shows that 18.2 % of mass is lower than 1.5 mm and the most of mass (60.8 %) is between 1.5 mm and 6.7 mm. The analysis is summarised in Table 2.

Table 2

Particle size analysis

Diameter of sieves, mm	Percentage distribution of fractions,%	Cumulated share, %
0	18.2	18.2
1.5	7.4	25.6
2.5	5.9	31.5
3.15	19.3	50.8
5.6	7.3	58.1
6.7	20.9	79.0
10	21.0	100.0

3.3 Emission of *Jatropha curcas* L. seed cake

The results of determining emissions of CO, CO_2, NO, NO_2 of *Jatropha curcas* L. seed cake are presented in Figure 1-3.

As it can be seen in Figure 1-3 the comparison with wood pellets shows that emission of CO and CO_2 *Jatropha curcas* L. seed cake is little bit lower than emission form wood pellets, but emission of NO and NO_2 is much higher, this is due to the presence of residual oil and higher content of nitrogen which achieves 3.12 % in *Jatropha curcas* L. seed cake and 0.1 % in woody pellets [7].

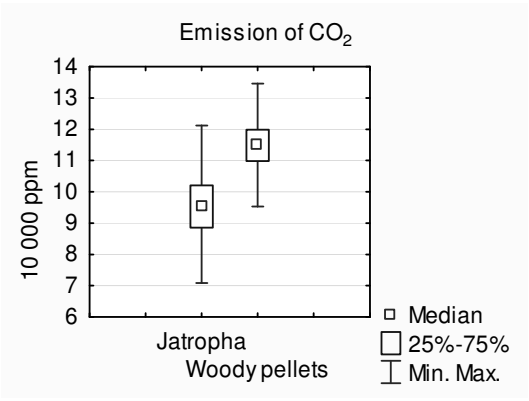

Fig. 1. **Emission of CO_2**

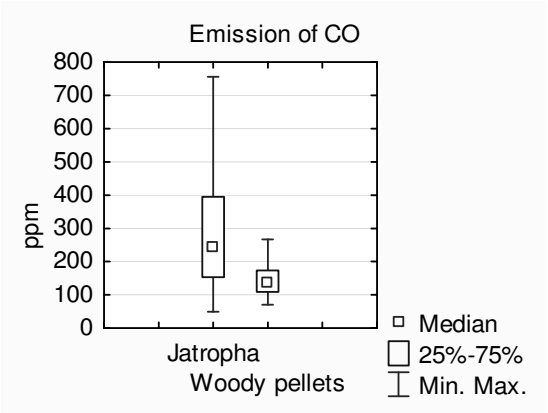

Fig. 2. **Emission of CO**

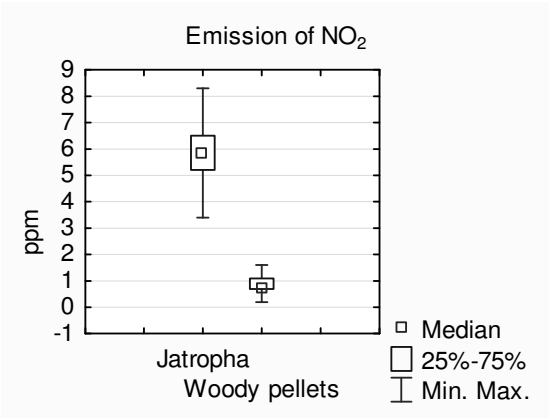

Fig. 3. **Emission of NO_2**

3.4 Possibility of use of *Jatropha curcas* seed cake as a substitute for pellets

An interesting way how to use *Jatropha curcas* seed cake is using it as substitution for pellets. The results of testing in the boiler Verner A25 show that the boiler was able to work continuously (10 hours test was performed) and *Jatropha curcas* seed cake is possible to be utilized in a similar kind of boilers (automatic boilers which are able to burn herbaceous pellets).

4. Conclusions

The performed determination of the energy properties shows that *Jatropha curcas* L. seed cake reaches very high values, heat of combustion is 19.11 $MJ \cdot kg^{-1}$and the calorific value is 17.56 $MJ \cdot kg^{-1}$. These numbers are much higher than wood pellets and briquettes are able to reach. *Jatropha curcas* L. seed cake has also very low water content, only 7.96 % and because of the residual oil content do not tend to water intake.

The emission analysis shows that emissions of CO and CO_2 *Jatropha curcas* L. seed cake are little bit lower than emissions from wood pellets, but emissions of NO and NO_2 are much higher, this is due to the presence of residual oil and higher nitrogen content.

The analysis shows that the best possible way of utilization of *Jatropha curcas* L. seed cake for energetic purposes is to use it as a substitute for the pellets. The performed analysis shows that it is possible to use *Jatropha curcas* L. seed cake in boilers designed for burning pellets without treatment.

The research allows affirming that *Jatropha curcas* L. seed cake could be used as a substitute for pellets. In the less developed countries there is large production with little utilization. The study shows

that *Jatropha curcas* L. seed cake could be a very promising type of alternative fuel and, because it is waste material from one of the most promising oil plants for biodiesel production, the production of this material is expected to be increasing.

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