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Analysis of physical and mechanical properties and of gross calorific value of Jatropha curcas seeds and waste from pressing process

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Abstract. The research was performed with an aim to investigate physical and mechanical properties and a gross calorific value of *Jatropha curcas* seeds and particular products (waste) of a pressing process. Sizes of seeds, an energy which is necessary for pressing an oil and a setting of the gross calorific value were tested parameters. Tests were performed at *Jatropha Curcas* seeds of a brown colour (that means gnaw). The pressing process waste amounts up to 80%. The proportion of the kernel mass to the coat mass is 1:0.62. From the research results it follows that the coat mass is 37.60%. The seed coat belongs among interesting material owing to the gross calorific value. For pressing the whole seeds it is necessary of about 30% higher energy than for pressing the kernels of *Jatropha curcas*.

Keywords: coat of seed, energy, kernel, pressing, seed, oil – cakes.

INTRODUCTION

In the long-term run of a sustainable development it is very important to use the energy resources in the most efficient way (Gürdil et al., 2009). Of course also the use of financial 'resources' should be optimized in order to reduce the impacts on human health and the environment as much as possible, while the created abundance is becoming more easily available to all parts of the world's population (Malaťák & Passian, 2011).

In recent years biofuels have obtained a considerable interest, due to the implementation of ruling and gradual replacement of fossil fuels. World research is focused mainly on searching of new and effective sources of biofuels. From the ecological point of view vegetable oil-based biofuels are in many aspects better than fossil fuels, such as in the agricultural machinery area (Pexa et. al., 2013). Potential place to obtain these biofuels is primarily in tropical and subtropical areas where facilities for the harvest a few times per year and yield maximization are.

A sustainability in the energy consumption area is inextricably linked with the search of new alternatives. It is one of the options that is currently preferred by the 'green energy', 'renewable energy sources' and others. The reason is the limited amount of fossil fuels. Another problem is the use of petroleum derivatives in the production area of polymeric materials. The availability of petroleum is limited due to the dynamical increase of energy consumption (Ružbarský et al., 2013).

One of production steps at gaining the oil is a pressing process (Kabutey et al., 2012). Wastes come into being from this process. These wastes are used as feed, fertilizer prospectively as fuel.

According to the requirements for biofuels and yield production tropical plant berries from the countries in the tropical zone are particularly suitable. In the tropical belt countries there are several dozens of prospective oleiferous plants as oil palm, coconut, cotton, soya, Jatropha curcas and others (Herák, et al., 2013a; Herák, et al., 2013b; Kabutey, et al., 2011).

A contemporary scientific literature pays attention namely to one of prospective produces which is a produce of the tropical and subtropical zones *Jatropa curcas*. In terms of analysis Jatropha curcas is one of the prospective crop in the area of tropical and subtropical belt (Petrů, et al., 2012; Herák, et al., 2013a;). Seeds of the plant Jathropa Curcas contain a high percentage of the oil which is wildly used – it is used e.g. at the production of the biofuels (Kabutey, et al., 2013; Samsuri & Zoveidaviapoor, 2014).

In the industrial production of the oil whole seeds are pressed, however there are processes in which only kernels are pressed. Due to this there is a need to determine the possible utility of the other seed subcomponents. Tests were performed at seeds of a brown colour (that means gnaw). The aim of research is an analysis of *Jatropa curcas* seed from the utilization point of view of the pressing process waste (a cake). Owing to the nature of cake it is not possible to use them as feed. Another source of the waste is a seed peel which comes into being during the pressing process of higher quality oil that means determined for the pharmacy (Herák, et al., 2013c; Ružbarský et al., 2013).

The research was performed with an aim to investigate physical and mechanical properties and a gross calorific value of *Jatropha curcas* seeds and particular products (waste) of a pressing process. Sizes of seeds, an energy which is necessary for pressing an oil and a setting of the gross calorific value were tested parameters.

MATERIALS AND METHODS

Tests were performed at seeds of a brown colour (that means gnaw) made in Indonesia. A humidity of tested seeds was 23%.

At first an analysis of tested seeds (200 pieces) was performed. A size and a mass of particular seeds were set. Further, masses of particular parts of the seed were set. The seeds mass was measured in a following way: seeds were measured before dividing the episperm (the kernel and the episperm together), subsequently the episperm and the kernel were divided and the kernel was weighed (alone).

The mass of the seeds was reviewed on analytic scales with the accuracy of 0.1 mg. The seeds sizes were measured by means of a digital sliding gauge Mitutoyo.

Gross calorific value evaluation of *Jatropha curcas* was performed with the brown coloured seeds that are overripe (Fig. 1). In the measurements there were used the samples of seeds that were crushed.

The gross calorific values were measured for seed coat, seed kernel, whole seed and cake (kernel with seed coat) (Figs 1 and 2). In the Fig. 3 there is a seed cut in which a portion of particular parts is visible.

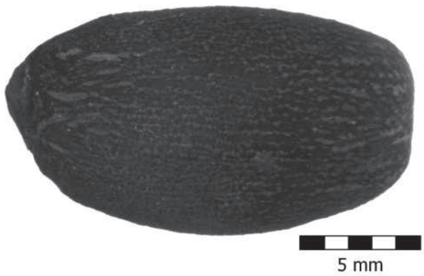


Figure 1. *Jatropha curcas* seed with coat.

Figure 2. *Jatropha curcas* seed kernel.

Individual parts of the seed were separated mechanically by hand and with using a special knife. An emphasis was placed on a minimal contamination of the parts.

A pressing was in progress at whole seeds and at kernels alone (Fig. 4). The pressing was in progress on the machine ZDM5t (500 kN) with a software TIRAtest (Fig. 5). A deformation speed was $10\ \mathrm{mm \cdot min^{-1}}$. The pressing equipment was of a cylindrical shape (60 mm). A dump was till the height 80 mm.

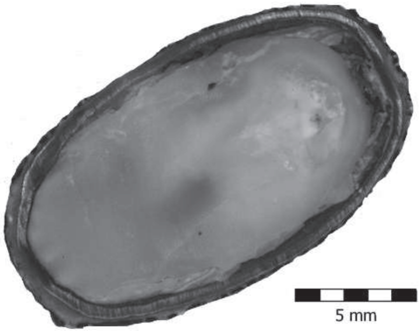


Figure 3. Cut through *Jatropha curcas* seed with coat.

Figure 4. Preparation of pressing.

The basic instrument to evaluate the gross calorific value of each variant of the experiment was calorimeter PARR 6200 Calorimeter (Fig. 6) and digital scales for accurate laboratory weighing. An oxygen bottle was used for tests. Experiments were performed in accordance with the standard CSN EN 14 918 (2010).

Individual prepared tested variants of experiments were mechanically crushed. To evaluate the gross calorific value for each variants of the experiment the material was prepared and weighed at intervals of 1 to 3 g. The seed was inserted into the test container where the wick was placed (the wick is to ignite the seed). Then the container was closed and there was created an air overpressure which is necessary for a combustion process. The second container was filled with two litres of distilled water, which is used for cooling. The container with the spacemen was placed into the container with distilled water and subsequently it was placed into the test area of calorimeter. The container shell (located test seed) is measured by sensors and another sensor measures the water temperature depending on time.

Figure 5. Pressing equipment and evaluation machine.

Figure 6. Testing instrument – PARR 6200 Calorimeter.

RESULTS AND DISCUSSION

When testing the seeds size following values were determined: the seed thickness 11.25 ± 0.43 mm, the seed length 18.27 ± 0.77 mm and the seed height 8.94 ± 0.50 mm. An average seed mass (calculated from the masses of 200 seeds) amounted 0.6476 ± 0.1117 g at the proportion of the kernel mass to the coat mass 1:0.62. The kernel mass was 0.4041 ± 0.0909 g. From the research results it follows that the coat mass is 37.60%.

Sirisomboon et al. (2007) ascertained different results. They determined the proportion of seeds kernel to 52% and seeds coat to 48%. At analysing 200 pieces of seeds imported from Indonesia 8% of bad seeds was ascertained. Fig. 7 shows the cut through the seed where the damage of the seed kernel is visible.

Graphical exemplification of the seed sizes of *Jatropha curcas* subcomponents was prepared by a program Statistica with method of least squares (MLS) as can be seen in Figs 8, 9 and 10. The Tukey’s HSD test was used for the statistical comparison of mean values.

The difference among the tested series is clear in the comparing of the mean data set values. In the light of statistic there is not homogeneity among the tested series.

It is clear from the results that the research results cannot be generalized on one average seed. Huge differences are among the seeds.

Figure 7. Cut through mouldy *Jatropha curcas* seed.

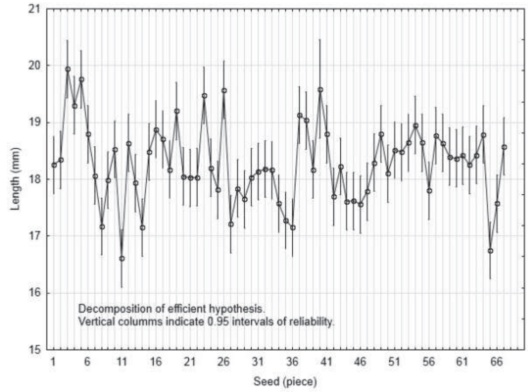


Figure 8. Length of *Jatropha curcas* seed.

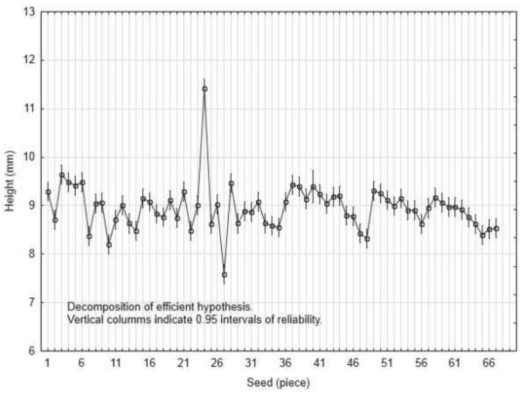


Figure 9. Height of *Jatropha curcas* seed.

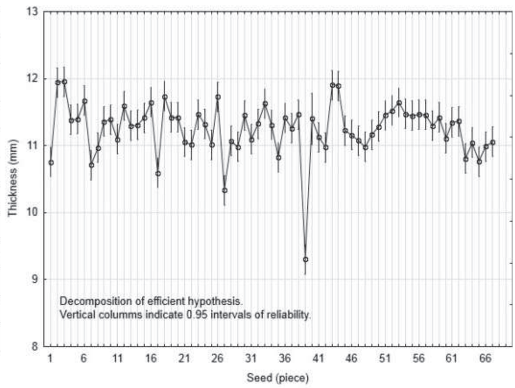
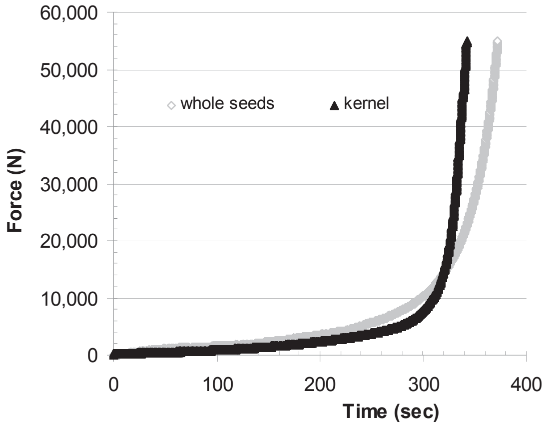


Figure 10. Thickness of *Jatropha curcas* seed.

Pressing was performed for getting oil – cakes from the seed and the kernel of *Jatropha curcas*. The measurement results evaluation was in progress according to the methodology of Herák (Herák, et al., 2013a). The course of the pressing process is visible in Fig. 11. The energy for the pressing amounted 439,450 J at the seeds and 307,507 J at kernels alone at the maximum loading force 55,000 N. The pressing process waste (the oil – cakes) are visible in Fig. 12.

Graphical exemplification of the gross calorific value results of *Jatropha curcas* subcomponents was prepared by bar chart with error bars Fig. 13. The difference among the tested series is clear in the comparing of the mean data set of gross calorific value and inconsumable residues.

The gross calorific value of testing variants exceeded the gross calorific value of wood (Ružbarský et al., 2013). Solid fuels made from woody biomass reach following gross calorific values: forest wood chips 18.74 MJ kg^{-1}, polar pellets 18.2 MJ kg^{-1}, energy sorrel spruce pellets 16.54 MJ kg^{-1}, lucerne pellets 16.61 MJ kg^{-1}, knotweed pellets 17.62 MJ kg^{-1} and oats grain 17.17 MJ.kg^{-1} (Malaťák & Passian, 2011).



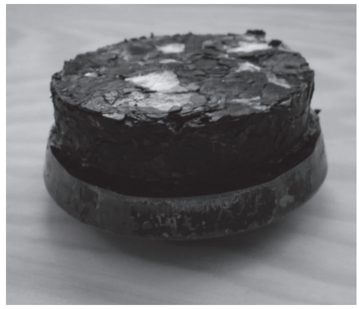


Figure 11. Pressing course.

Figure 12. Oil – cakes from pressing process of whole seeds.

Tested materials from *Jatropha curcas* seeds reach good results. Gross calorific value results of tests of orientation (compressed oxygen was used at the tests) can be used as a starting point for next experiments.

The gross calorific value of the oil – cakes of *Jatropha curcas* is of 31% on average lower than of the seeds. It follows from the results that it is effective using of the waste.

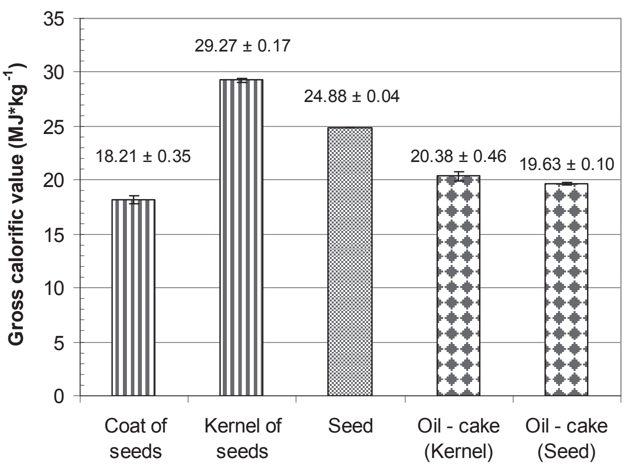


Figure 13. Gross calorific value of particular *Jatropha curcas* products.

CONCLUSIONS

In recent years biofuels have obtained considerable interest, due to the implementation of ruling and gradual replacement of fossil fuels. World research is focused mainly on searching of new and effective sources of biofuels. Potential place to obtain these biofuels is primarily in tropical and subtropical areas where are facilities for the harvest a few times per year and yield maximization. However in these areas there is problematic infrastructure and availability of efficient technologies very often event.

In this paper *Jatropha curcas* seed is analysed from the view of the size and mass of the seed, the influence on the pressing process and the gross calorific value of the subcomponents. These conclusions can be determined:

- The gross calorific value of the oil – cakes of *Jatropha curcas* is of 31% lower than at seeds.
- The pressing process waste (oil – cakes) amounts up to 80%.
- Sizes and a mass of the seed – It is clear from the results that the research results cannot be generalized on one average seed. Huge differences are among the seeds.
- The proportion of the kernel mass to the coat mass is 1:0.62. From the research results it follows that the coat mass is 37.60%. The seed coat belongs among interesting material owing to the gross calorific value comparable with the wood.
- For pressing the whole seeds it is necessary of about 30% higher energy than for pressing the kernels of *Jatropha curcas*.

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