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Energy from seed shells of *Jatropha curcas*

The seed shells of the oleiferous fruit Jatropha curcas is a promising fuel in tropical and subtropical countries. The thermal energy can be applied in many ways for example for drying Jatropha nuts or processing biodiesel from Jatropha oil. The calorific value of the shells is between 16-17 MJ/kg and thus similar to wood, which is a main energy source in developing countries until now.

Keywords
Jatropha curcas, processing residues, combustion, bioenergy

Abstract
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During the processing of plant oil from Jatropha seeds usually the whole seed (kernel and shell) was used. The press cake whitch accrues as by-product is rich on protein and could be used after a detoxification process as animal feed. However, through the high content of shells in the press cake, the content of crude fiber was also high. This could be a disadvantage for the use as animal feed. Therefore, the production of a high value, protein rich animal food from the press cake of Jatropha seeds without shells was preferred. The increasing areas of plantations of *Jatropha curcas* in India, China, and Indonesia as well as in South America and Africa will lead to an increased amount of *Jatropha curcas* in future.

The shells of the seeds are promising to be an alternative fuel for these countries, because they appear as a by-product during the processing of Jatropha oil and can not be used for any other application until now. The thermal energy released during the combustion can be applied in many ways e.g. for drying of *Jatropha* nuts or during the production process of biodiesel from Jatropha oil. The calorific value of the shells is between 16-17 MJ/kg and thus comparable to rice husks or moist wood, which are the main energy sources in rural areas of developing countries till this day. The Jatropha seed was cracked by a desheller and separated by using an air separator into kernels and shells. The shells of the *Jatropha curcas* nut from the deshelling process are free flowing material comparable to rice husks (**figure 1**).

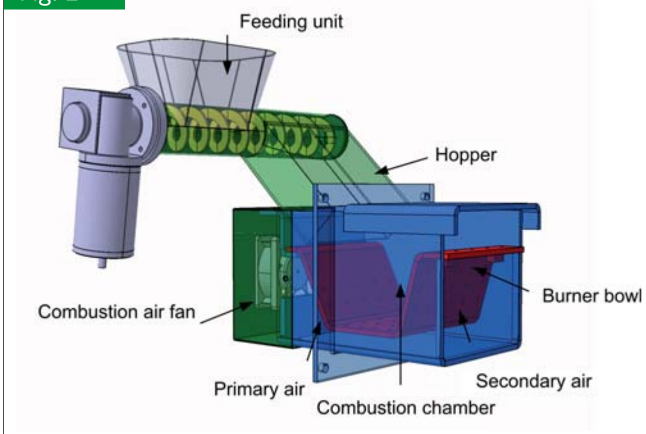
In the first step neither pelletizing nor briquetting are intended to achieve a reduction of volume or an increase of energy density. However, that excludes the transportation of this alternative fuel over long distances. Generally combustion units for such fuels are established, yet have to be optimized regarding the combustion process and the exhaust gas quality [2].

Furthermore, the operation of a combustion unit affects the efficiency and emergence of toxic exhaust gas components. Hence ash content and ash quality which are significantly responsible for a failure-free operation were comprised in the analysis. In this study the physical and chemical properties of Jatropha shells as fuel have been investigated, as well as a robust functional combustion unit has been designed.

Fig. 1

Shells of Jatropha curcas. Photo: Kratzeisen

Fig. 2



3D-Catia model of combustion unit

Material & Methods

The combustion unit has been designed after the principle tilting furnace/without grate/bowl burner after [3]. Paying particular attention to the later site of operation of the combustion unit (tropical and subtropical countries) complex mechanical parts have not been implicated in the construction to arrange a reliable and easy operation and maintenance of such a combustion unit. The burner is started by adding a small amount of Jatropha shells through the dosing screw. These shells in the burner bowl are ignited manually by the use of firelighters. Now fuel and combustion air are added constantly till the desired adjustment according to the power is achieved.

Figure 2 shows a 3D model of the combustion unit constructed with the CAD-software CATIA. The model made using this 3D-application is the basis for a later fluid dynamic simulation using the additional module 'FLUENT for CATIA V5'. The combustion chamber as basic unit consists of angled stainless steel sheet to which the components feeding unit with hopper and combustion air fan are attached. The burner bowl is performed as drawer and the cap is removable, which alleviates a rotational cleaning of the combustion chamber where the combustion unit is cleaned from combustion residues.

The combustion unit is inserted in a chamber built of brick in which the burnout of the flue gases as well as the heat exchange is realized. To keep the combustion unit simple in the first step a control of the combustion process is left out on purpose. The adjustment of the combustion air has been detected empirically by using of the flue gas control. The physical properties, the composition of the fuel and the ash melting temperatures have been determined according to methods shown in **table 1** and **table 2**.

Table 1

Properties of Jatropha curcas shell

Parameter	Result	Method
Calorific value, MJ/kg	16.5±0.1	DIN 51 900-2
Water content, %	8.9±0.3	DIN 51 718
Particle density, g/cm³	0.9±0.1	DIN CEN/TS 15150
Bulk density, kg/m³	250.8±0.5	DIN CEN/TS 15103
Angle of repose, °	44.9±0.4	DIN EN 12047
Carbon content, %	50.9	DIN 51 732
Hydrogen content, %	5.8	
Nitrogen content, %	0.8	
Oxygen content, %	39.5	
Chlorine content, %	0.1	DIN 51 577-3
Sulphur content, %	0.1	DIN EN ISO 20884
Ash content, %	3.8	DIN 51 719

Results

The physical properties as well as the composition of the fuel are presented in **table 1**. The high ash content of 3.8% in comparison to wood with about 0.5% [3] is remarkable. Furthermore the elements nitrogen, chlorine and sulphur have to be mentioned, which have effects on the composition of flue gas emission during the combustion. In comparison to fire wood the contents are 6 times, 20 times and 6.5 times elevated, in this order [3].

Table 2 shows the ash melting temperatures that are extremely important for the reliable operation of the combustion unit. At low ash melting temperatures e.g. 700 °C for grain, slagging in the combustion chamber and on the grate can be avoid by special design features only. The melting temperature of ash from Jatropha shells is 980 °C and therefore comparable to stem-like fuels [3]. Cooling down the burner bowl with primary air limits its maximum temperature and slagging which would close the air inlet wholes, can be avoided. Thereby, a continuous supply with primary air is assured and the combustion process is maintained.

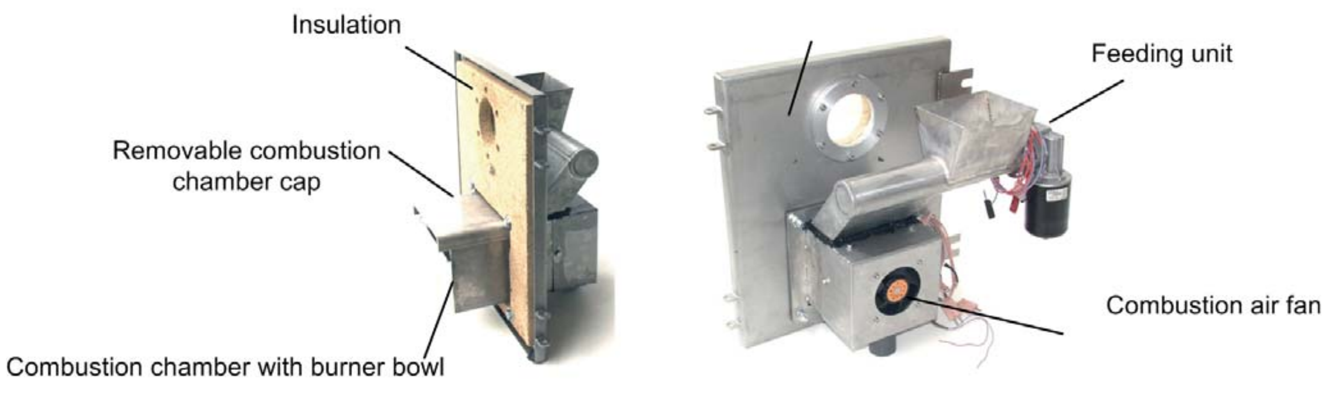
Figure 3 shows the designed combustion chamber. The maximum power which can be achieved was about 20 kW with combustion efficiency of 91%. This equates a mass flow of 4.8 kg of Jatropha seed shells per hour. During the experiments an agglomeration of ash melting on the grate in the combustion chamber could not be observed. An ash bed with an approximate high of 2.5 cm was built during the combustion on the grate. The ash could be removed easily after the tests. A clogging of the air supply holes on the grate was not observed.

Table 2

Ash melting temperatures

Parameter	Result	Method
Ash softening point, °C	980	DIN 51 730
Hemisphere temperature, °C	>1550	
Flow point, °C	>1550	

Fig. 3



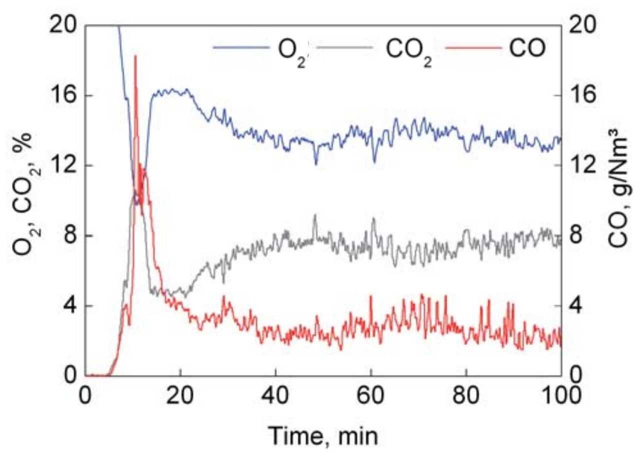
Combustion unit

In **figure 4** the composition of the flue gas during the combustion of Jatropha seed shells with a power of 20.2 kW is shown. The concentration of carbon monoxide ranges, related to an oxygen content of 13% after the start-up phase, for the rest of the operation time around 2.8 g/m³. According to the 1. BimschV, the threshold value for carbon monoxide for combustion units with a power less than 50 kW is 4 g/m³ in the case of firewood [1]. The concentration of carbon monoxide in the experiment was comparable to emissions of basic heaters - and tiled heaters [3].

Conclusions

The combustion of Jatropha shells is possible without previous processing e.g. pelletizing, whereby the fuel costs can be kept low. However, the fuel should be applied to the combustion locally at its point of origin, in order to avoid transportation costs. The concentration of carbon monoxide is below of existing regulations. However, in a next step a control of combustion quality will be implemented. The problems of softening and fusion of the ashes in the investigated combustion unit does not occur.

Fig. 4



Composition of the flue gas related to 13 % oxygen during operation with a power of 20.2 kW

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