

## Mechanical behaviour of selected bulk oilseeds under compression loading

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**Abstract.** Pressing of vegetable oils plays an important role in modern agriculture. This study was focused on the linear pressing of soybean seeds (*Glycine max L.*), Jatropha seeds (*Jatropha curcas L.*) and palm kernel (*Elaeisguineensis*). For pressing test the compressive device (ZDM, model 50, Germany) was used. The maximum pressing force of 100 kN with a compression speed of 1 mm s<sup>-1</sup> was used to record the force–deformation characteristics. The pressing vessel with diameter 60 mm and initial height of seeds 80 mm were used. The specific energy per gram of oil of soybean, palm kernel and Jatropha was 158.92 ± 7.21, 128.78 ± 8.36 and 68.26 ± 5.94 J/goil-1, respectively. The oil content of soybean, palm kernel and Jatropha was 20.4 ± 1.23, 44.7 ± 2.27 and 34.2 ± 1.75 %, respectively. Water concentration, dynamic and kinematic viscosity of obtained oils was also determined.

### 1. Introduction

Production of vegetable oil is one of the most important part of modern agriculture. Vegetable oils have been used for centuries for food and non-food applications [1]. A large part of obtained oil is edible oils, which are used directly in food industry as follows: mayonnaise, margarine, cooking fats etc. [2]. Separation of oil from oilseeds is an important processing operation. The process has a significant effect on the quality and quantity of protein and oil obtained from the oilseeds [3]. One of the most common methods of obtaining oil is mechanical pressing. This method is based on mechanical compression of oleaginous materials. The vegetable oil obtained via this method is characterized by high quality and can be used for special applications [4]. The most commonly used equipment for mechanical pressing is screw press. This method is the most popular oil extraction as the process is simple, flexible, continues and safe [5]. For designing screw pressing technology is necessary to know the basic mechanical behaviour of bulk oilseeds by linear pressing. For this study soybean (*Glycine max L.*), Jatropha (*Jatropha curcas L.*) and palm kernel (*Elaeisguineensis*) were chosen, because this seeds represent the main oilseeds in Indonesia. Some of the pressing parameters of this seeds have already been determined [2; 3; 6; 7; 8; 9]. The aim of this study was to determine the pressing curves, specific energy, amount of oil and initial slope of deformation curve of selected oilseeds. The content of water in oil and viscosity of the obtained oil were also determined.

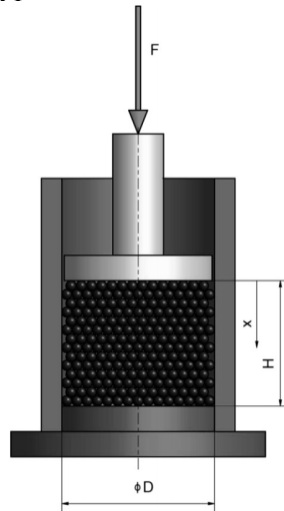


## 2. Materials and Methods

Whole seeds of soybean (*Glycine max L.*), Jatropha (*Jatropha curcas L.*) and palm kernel (*Elaeisguineensis*) obtained from North Sumatra, Indonesia were used for the compression test. The moisture content, which was determined using standard oven method, ASAE method (ASAE S410.1 DEC97, ASAE, 1998), for soybean, Jatropha and palm kernel was 7, 8, 8,9 and 6,2 %, respectively. The maximum quantities of oil present in each batch of the oilseeds used for this study were determined using the Soxhlet extraction technique. This was done according to the CSN method (CSN EN ISO 659 – 46 1034, CSN, 2011).

### 2.1. Compression test

To determine the relationship between the pressing force and deformation, the compressive device (ZDM, model 50, Germany) was used to record the course of deformation function. The pressing vessel and plunger (Fig. 1) of diameter 60 mm were used. The bulk seeds of initial height 80 mm were measured and pressed at the rate of 1 mm.s<sup>-1</sup> under room temperature. The measuring range of force was between 0 kN and 100 kN. The experiment was repeated three times for each type of seeds.



**Figure1.** Scheme of pressing vessel

The volume energy is the area under the compressive force-deformation curve and was calculated using Eq. 1.

$$E_x = \sum_{n=0}^{n=i-1} \left[ \left( \frac{F_{n+1} + F_n}{2} \right) \cdot (X_{n+1} - X_n) \right] \quad (1)$$

where:  $E_x$  – deformation energy, J;  $F_{n+1}$  and  $F_n$  – values of compressive force, N;  $X_{n+1}$  and  $X_n$  – values of seed deformation, m;

The initial slope of deformation curve was determined as the slope of the tangent at zero time.

### 2.2. Oil analysis

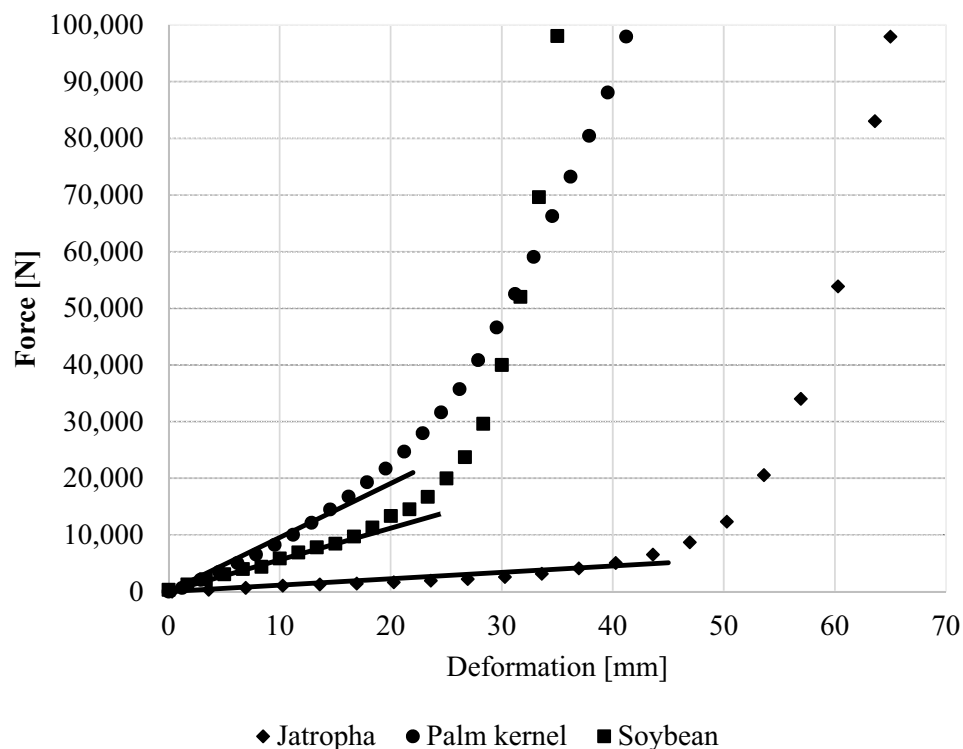
The Soxhlet apparatus was used to determine the oil content of seeds. For Soxhlet extraction 10 g of find ground seeds was extracted with petroleum in a Soxhlet apparatus for 6 h at 60°C.

The Coulometer WTD developed to perform routine analysis of moisture, was used to measure the content of water in given oil samples. Employing the coulometric method allows detection of small or even trace amounts of water in a variety of solutions; including, but not limited to, solutions based on organic acids, alcohols, esters, hydrocarbons and many other organic solvents.

Stabinger Viscometer was used for determination of viscosity. This analyser covers a wide measuring range with one measuring cell and provides precision comparable to gravimetric capillary viscometers.

### 3. Results and discussion

Measured data of individual pressing curve for soybean, Jatropha seed and palm kernel are shown in Fig. 2. The compression test was repeated three times for each type of seeds.



**Figure 2.** Measured amounts of pressing characteristic of different type of oilseeds

The oil content of seeds was determined by Soxhlet apparatus and is shown in Table 1. The parameters of mechanical pressing of the 3 oilseeds are presented in Table 1. Deformation at peak load 100 kN ranged between 34-35, 41-43 and 64-66 mm in soybean, palm kernel and Jatropha seeds. The deformation was significantly higher in Jatropha seeds than in the other seeds (Table. 1).

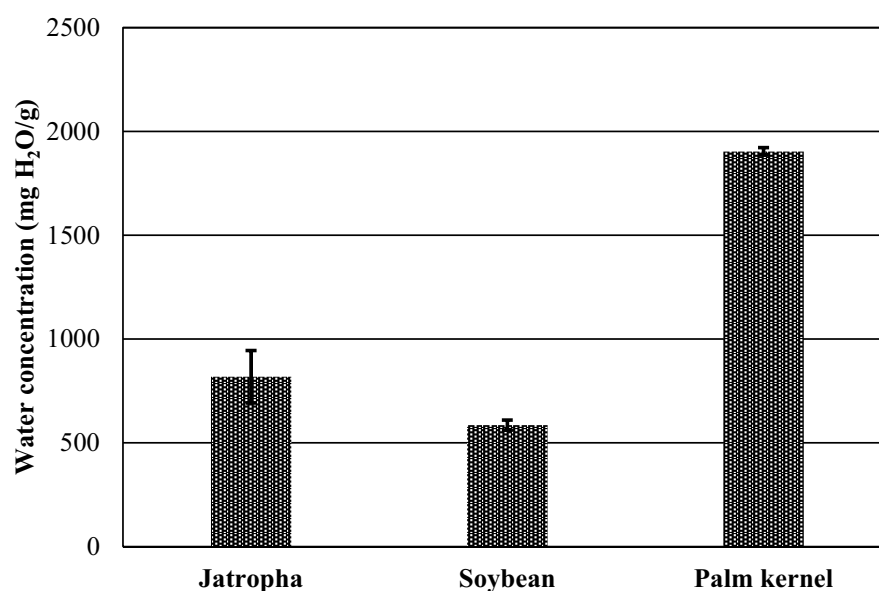
**Table 1.** Mechanical parameters of the bulk oilseeds loaded compressively to 100 kN

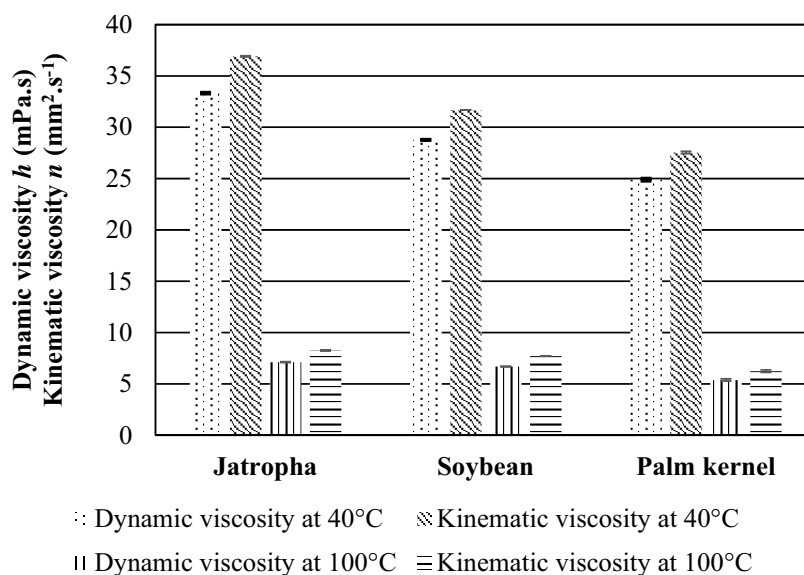
	Soybean	Palm kernel	Jatropha
<b>Oil content [%]</b>	20.4 ± 1.23	44.7 ± 2.27	34.2 ± 1.75
<b>Initial mass [g]</b>	167.1 ± 8.87	152.3 ± 6.52	77.2 ± 3.15
<b>Gained oil [g]</b>	4.2 ± 0.22	10.5 ± 0.69	10.65 ± 0.56
<b>Initial slope of deformation [N.m<sup>-1</sup>]</b>	588.57 ± 28.38	736.67 ± 44.63	99.96 ± 4.58
<b>Strain [-]</b>	0.44 ± 0.03	0.53 ± 0.02	0.81 ± 0.04
<b>Deformation energy [J]</b>	670.56 ± 32.22	1237.64 ± 88.48	726.99 ± 45.51
<b>Specific energy [J.g<sub>oil</sub><sup>-1</sup>]</b>	158.92 ± 7.21	128.78 ± 8.36	68.26 ± 5.94

(mean ± standard deviation)

Strain in bulk seeds of soybean, palm kernel and Jatropha seeds at a peak compressive force of 100 kN was 0.44, 0.53 and 0.81, respectively. Mean deformation energy at peak compression was 670.56, 1237.64 and 726.99 J, for 80 mm initial height of soybean, palm kernel and Jatropha seeds, respectively. The energy demands for the deformation of soybean and Jatropha seeds at peak load were significantly less than the energy requirement for the deformation of palm kernel at the same load (Table 1). Similar mechanical properties of the Jatropha seeds were also found by other authors [7; 8; 10]. The oil obtained from individual seeds is also shown in Table 1. From these values the specific energy per gram of oil was determined. From Table 1 is evident that the energy demand to obtain 1 g of oil in the case of Jatropha seeds was significantly less than the energy requirement for the other seeds. Mechanical properties of soybean were also determined by other authors [11; 12]. Very similar results of pressing palm were also found by other authors [13, 14].

The measured values of water concentration and viscosity of oils are shown in Fig. 3 and Fig. 4.

**Figure 3.** Water concentration of analysed oils



**Figure 4.** Dynamic and kinematic viscosity at 40°C and 100°C of analysed oils

It is obvious that the highest concentration of water was measured in palm kernel oil sample in Figure 3. Water content has also impact on value of viscosity. The lowest value of viscosity was measured within palm kernel shown in Figure 4. Some results of soybean oil has been already determined.

#### 4. Conclusion

This study was focussed on the Mechanical behaviour of soybean, palm kernel and Jatropa seeds under compression loading. Individual pressing curves of seeds were determined and analysed. Results indicate that the specific energy per gram of oil at Jatropa seeds was approximately two times lower than the energy requirements for other seeds. The oil content of soybean, palm kernel and Jatropa seeds by Soxhlet extraction was also determined. Oil analysis of obtained oils such as water concentration, dynamic and kinematic viscosity was also determined. The results obtained in this study can help with the design of the pressing technology.

#### Acknowledgment

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