MECHANICAL BEHAVIOUR OF OIL PALM KERNELS (*ELAEIS GUINEENSIS*)

A. Kabutey, M. Divišová, L. Sedláček, W.E. Boatri, T. Svatoňová, R. Sigalingging

Czech University of Life Sciences Prague, Faculty of Engineering, Prague, Czech Republic

Mechanical properties including compressive force, deformation (mm), deformation energy (J), and hardness (N mm^{-1}) were investigated for heat treated palm kernels in a compression loading test. The kernels were measured at pressing heights 60 and 80 mm respectively using the pressing vessel diameter 60 mm. Maximum pressing force 100 kN with a compression speed 1 mm s^{-1} was used to record the force-deformation characteristics. Maximum force was applied on the initial volume of material three times. The amounts of deformation, deformation energy, and kernel oil (g) decreased linearly in relation to repeated pressing of the initial volume of material. In contrast, kernel hardness increased. A little significant change in the kernels rate of deformation was observed in the entire test. However, in each test there was a measurable amount of kernel oil. The study indicated that a force greater than 100 kN would be needed to achieve higher percentage of kernel oil from heat treated palm kernels under compression loading.

oil palm kernels; heat treatment; force; pressing height; deformation energy; kernel oil

INTRODUCTION

Palm oil is an edible vegetable oil derived from the mesocarp of the oil palm fruit (*Elaeis guineensis*) which belongs to the *Palmae* family (Owolarafe et al., 2007). The plant originates from the tropical rain forest region of West Africa and occurs in the southern latitudes of Cameroon, Cote d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo, and the equatorial region of Angola and the Congo. The world production of palm oil increased tremendously during the last 30 years as a result of rapid expansion of oil palm plantation in South East Asian countries spearheaded by Malaysia and Indonesia. Many countries plant oil palm to produce the oil to cover their local consumption but Malaysia and to a certain extent Indonesia are unique in that the production of palm oil is meant for export. Therefore Malaysia and Indonesia have emerged as major producers of palm oil (Basiron, 2007).

The oil palm bears its fruit in bunches varying in weight from 10 to 40 kg. Each fruit is made up of an outer skin (exocarp), a pulp (mesocarp) the oil content of which makes 70–75% of its total weight, a central nut consisting of a shell (endocarp), and the kernel, which itself contains an oil quite different from the palm oil, resembling rather coconut oil. The difference is in colour. Palm mesocarp oil is red while raw palm kernel oil is not red due to the lack of carotenoids (Keshvadi et al., 2011). The harvested palm fruit bunches pass through processing stages of sterilization, striping, digestion, and palm oil extraction using a solvent or mechanical screw press. Palm nuts and fibers are left as a residue. The nuts are dried and cracked into palm kernel and shell.

The traditional process is simple, but very tedious and inefficient. The palm oil contains a range of fat-soluble vitamins (A, D, E, and K) and essential fatty acids which are necessary for the healthy functioning of the body (O'Brien, 2008; Akinoso, Raji, 2011). Apart from the use of palm oil as food and other industrial purposes, it is among the alternative energy sources for biodiesel production. However, technology improvement for processing palm fruit, nut, and kernel requires accurate information on both the physical and mechanical properties. For instance, stripping and pressing are important unit operations in palm oil processing. The efficiency of these unit operations rely on the mechanical behaviour of palm fruits under compression loading since they involve the application of pressure (Raji, Favier, 2004).

According to Raji, Favier, 2004 or Herak et al., 2010, the pressing force is one of the key factors that can influence the energy demands of vegetable oil extraction. Determining the correct value of the pressing force during the design of the processing machines would enhance the oil recovery to minimize energy input. The study performed by Akinoso, Raji, 2011 showed that a greater force was required to cause deformation of kernels than nuts and fruits. However, at lower pressing force of the fruits, deformation value was the highest followed by nuts and then kernels. In the same study, greater energy was required to compress the palm kernel than the mesocarp pressing and palm nuts cracking. Actually,

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in the literature, there is very limited information on the mechanical behaviour of oil palm fruits, nuts, and especially the kernels. The objective of this research was to investigate the mechanical properties of heat treated kernels under compression loading where the deformation (mm), energy (J), and hardness (N mm^{-1}) were measured respectively. The amount of kernel oil was also determined.

MATERIAL AND METHODS

A heat treated palm kernel (Fig. 1) collected from Eastern Region, Ghana, was used for the compression test. The electronic balance Kern 440-35 (Kern & Sohn GmbH, Balingen, Germany), having an accuracy of 0.01 g, was used to weigh the samples before and after oven drying. The standard hot air oven method with a temperature setting of 105°C and a drying time of 17 h (I S I , 1966) was used. Kernel moisture content was found to be 15.31% (wet basis) using the Equation (1) given by B l a h o v e c , 2008:

$$MC_{W.b.} = \left[\frac{Mi - Mc}{Mi}\right] \cdot 100\% \quad (1)$$

where:
$MC_{W.b.}$ = moisture content on wet basis
Mi = initial sample weight (g)
Mc = sample weight (g) after oven drying

Compression test and parameters determined

The compression equipment ZDM 50-2313/56/18 with a chart recorder (VEB, Dresden, Germany) and pressing vessel diameter 60 mm (Fig. 2) were used for the compression test. The kernels were pressed at heights 60 and 80 mm at a pressing rate 1 mm s^{-1} and load100 kN. For each measured height, three pressing tests were done, that is, the same volume of material was repeatedly pressed three times. The force-deformation curves obtained from the compression test were analyzed using Mark Mitchell Software Engauge Digitizer (Version 4.1., 2002) to measure the geometry information. The pressing force and seed deformation values were obtained directly from the compression analysis. Deformation energy was determined from the area under the force-deformation curve (G r z e g o r z , 2007; H e r a k et al., 2010, 2012; K a b u t e y et al., 2012a). Kernel hardness was calculated as the ratio between the pressing force and kernel deformation.

RESULTS AND DISCUSSION

The study examined the mechanical properties such as the pressing force, deformation (mm), deformation energy (J), and hardness (N mm^{-1}) of heat treated palm kernels. The relationship between the pressing force and kernel deformation characteristics at kernel heights 60 and 80 mm is shown in (Figs. 3–4). Based on this dependency, the amount of kernel oil (Table 1, Fig. 5) in each test with respect to the applied force at 100 kN was chief in importance. Expectedly, deformation and deformation energy (Table 2, Figs. 6–7) decreased in relation to repeated kernel pressing. In the first initial kernel pressing height, a very slight change of kernel deformation was observed. Subsequent pressing of the slightly deformed kernels was done two more times to observe the rate of deformation without kernel oil. In the entire test, the kernels showed no flattened behaviour and more repeated tests could have been done to ensure permanent deformation without

Fig 1. Heat treated palm kernels

Fig. 2. Pressing vessel with plunger and a caked kernel oil

Table 1. Determination of kernel oil

Pressing height (mm)	*Repeated kernel pressing (-)	Kernel weight before pressing(g)	Kernel weight after pressing (g)	Kernel oil(g)
60	1	112.62	95.68	16.94
	2	95.68	85.75	9.93
	3	85.75	78.66	7.09
80	1	150.14	127.83	22.31
	2	127.83	116.63	11.20
	3	116.63	108.03	8.60

* Initial volume of material

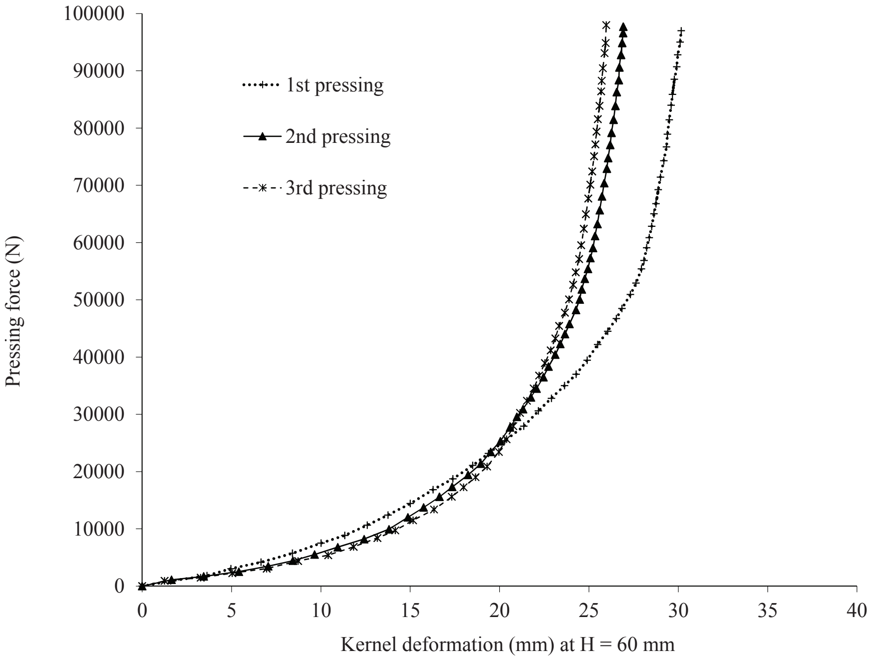

Fig. 3. Dependency between force and deformation for kernel height, H = 60 mm

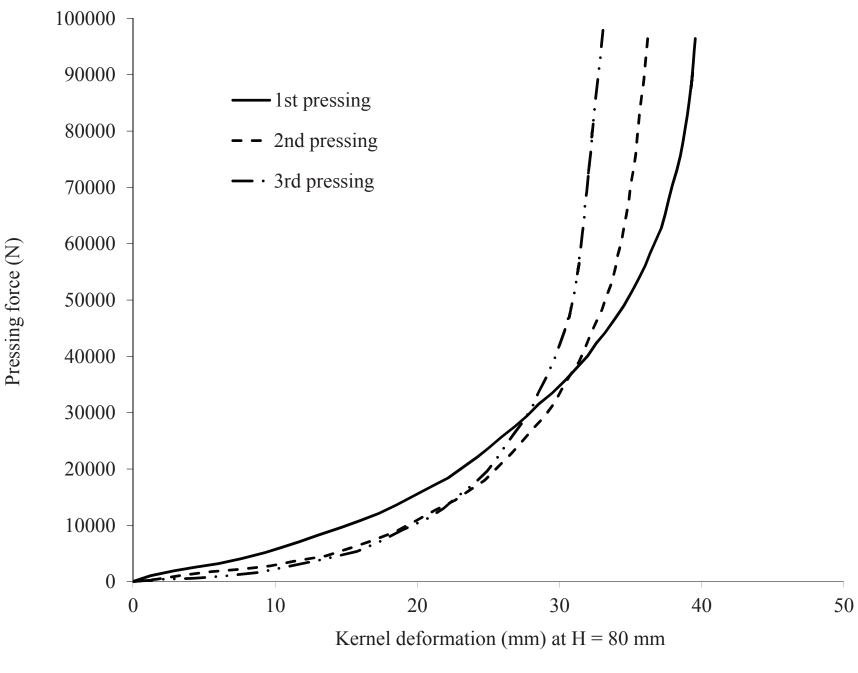

Fig. 4. Dependency between force and deformation for kernel height, H = 80 mm

Table 2. Mechanical properties of heat treated palm kernels

Pressing height (mm)	*Repeated kernel pressing (-)	Pressing force (N)	Kernel deformation (mm)	Deformation energy (J)	Kernel hardness (N mm^{-1})
60	1	96973.7	30.16	641.12	3215.30
	2	97700	26.96	493.77	3623.88
	3	97998.5	25.97	426.81	3773.52
80	1	96416.9	39.55	886.21	2437.84
	2	97125.1	36.23	613.24	2680.79
	3	97876.2	33.06	479.59	2960.56

* Initial volume of material

oil flow. This shows that a force greater than 100 kN would be required to achieve higher output of kernel oil from palm kernels subjected to heat treatment under compression loading test. The results also show that in relation to oil recovery with minimum energy input, the pressing force plays an important role (Raji, Favier, 2005; Herak et al., 2010).

Separately, an increasing relationship was found for both the pressing force and kernel hardness (Figs.8–9) in relation to repeated initial volume of material. This also indicates that palm kernel at high heat treatment time is likely to create some problems during their processing such as the resistance to a lower force. The result was different compared to *Jatropha curcas* L. seeds where seed hardness decreased with heat treatment (Kabutey et al., 2012b).

Finally, there is a direct relationship between deformation and deformation energy in relation to volume of material. Increasing the volume will directly increase the deformation and deformation energy (Herak et al., 2012; Kabutey et al., 2012b). Other pressing factors such as moisture content and temperature can also influence positively the amounts of deformation and deformation energy of oilseeds under compression loading (Kabutey et al., 2011, 2012a).

CONCLUSION

A force greater than 100 kN would be required to obtain higher amount of kernel oil from heat treated kernels under compression loading. Kernel hardness increased and as a result more energy was used to compress the oil. A study is on-going by considering the variation of the pressing force and heat treatment time on the amount of palm kernel oil under compression loading. However, to achieve the cost-effective

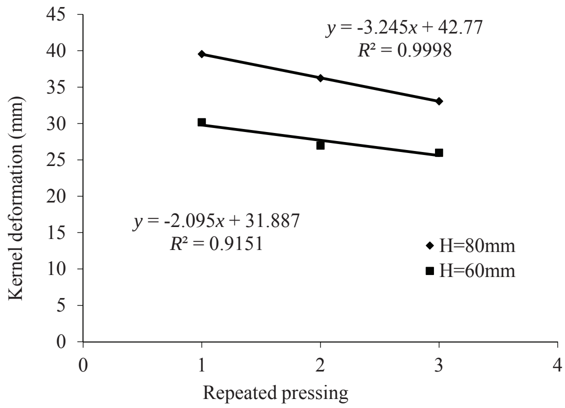

Fig. 6. Dependency between kernel deformation in relation to repeated pressing

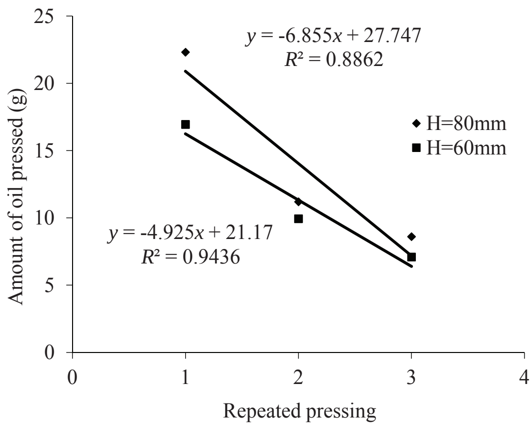

Fig.5. Dependency between kernel oil in relation to repeated pressing

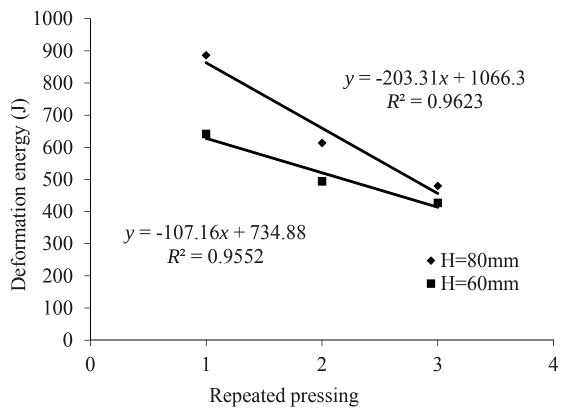

Fig. 7. Dependency between deformation energy in relation to repeated pressing

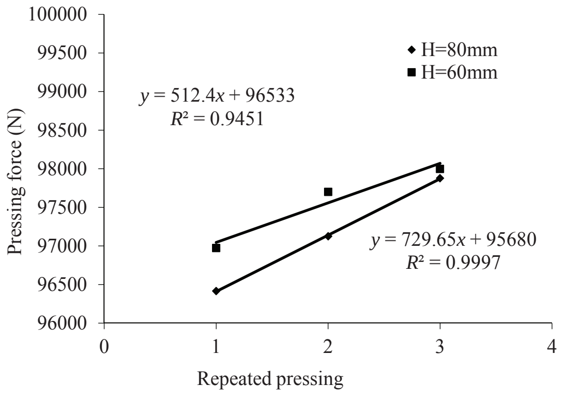

Fig. 8. Dependency between pressing force in relation to repeated pressing

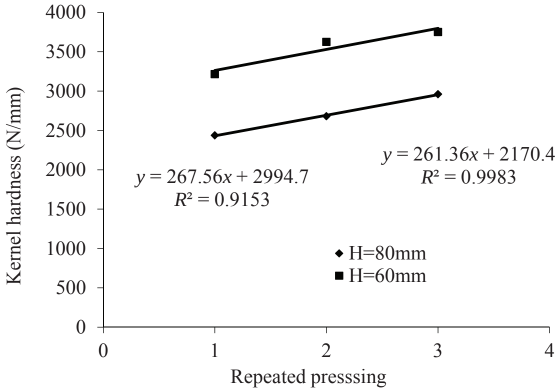

Fig. 9. Dependency between kernel hardness in relation to repeated pressing

technological improvement of oilseed processing, knowledge of the mechanical behaviour of oilseeds and operational parameters such as pressing time, pressing temperature, and moisture content are necessary to consider.

REFERENCES

Blahovec J., (2008): Agromaterials-Study Guide-Czech University of Life Sciences Prague, 7-8.

Akinoso R, Raji AO (2011): Physical properties of fruit, nut and kernel of oil palm. International Agrophysics, 25, 85–88.

Basiron Y (2007): Palm oil production through sustainable plantations. European Journal of Lipid Science and Technology, 109, 289–295.

Grzegorz L (2007): Fracture toughness of pea, Weibull analysis. Journal of Food Engineering, 83, 436–443.

Herak D, Gurdil G, Sedlacek A, Dajbych O, Simanjuntak S (2010): Energy demands for pressing *Jatropha curcas* L. seeds. Biosystems Engineering, 106, 527–534.

Herák D, Kabutey A, Sedláček A, Gürdil G (2012): Mechanical behaviour of several layers of selected plant seeds under compression loading. Research in Agricultural Engineering, 58, 24–29.

ISI (1966): Indian standard methods for analysis of oilseeds, New Delhi: Indian Standard Institute. IS 3579.

Kabutey A, Herák D, Sedláček A (2011): Behaviour of different moisture contents of *Jatropha curcas* L. seeds under compression loading. Research in Agricultural Engineering, 57, 72–77.

Kabutey A, Sedláček A, Divišová M, Svatoňová T (2012a): Heat treatment temperature of *Jatropha curcas* L. seeds under compression loading. Scientia Agriculturae Bohemica, 43, 116–121.

Kabutey A, Herák D, Chotěborský R, Navrátilová M (2012b): Model for energy and deformation determination of selected oilseeds under compression loading. Research in Agricultural Engineering, 58, 155–158.

Keshvadi A, Endan JB, Harun H, Ahmed D, Saleena F (2011): The relationship between palm oil index development and mechanical properties in the ripening process of Tenera variety fresh fruit bunches. Research Journal of Applied Sciences, Engineering and Technology, 3, 218–226.

O'Brien RD (2008): Fats and Oils, Formulating and Processing for Applications. Third Ed. Technical Publication Press, Lancaster, USA.

Oworlarafe OK, Olabige MT, Faborade MO (2007): Physical and mechanical properties of two varieties of fresh oil palm fruit. Journal of Food Engineering, 78, 1228–1232.

Raji AO, Favier JF (2004): Model for the deformation in agricultural and food particulate materials under bulk compressive loading using discrete element method II: theory, compression of oilseeds. Journal of Food Engineering, 64, 373–380.

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Corresponding Author:

Ing. Abraham K a b u t e y , Czech University of Life Sciences Prague, Faculty of Engineering, Department of Mechanical Engineering, Kamýcká 129, 165 21 Prague 6-Suchdol, Czech Republic, phone: +420 224 383 186, e-mail: kabuteyabraham@yahoo.com