Model for energy and deformation determination of selected oilseeds under compression loading – Short communication

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Abstract

Kabutey A., Herák D., Chotěborský R., Navrátilová M., 2012. **Model for energy and deformation determination of selected oilseeds under compression loading – Short communication**. Res. Agr. Eng., *58*: 155–158.

Compression loading test was performed to determine the dependency between force and deformation of jatropha, sunflower and rape seeds with respect to different pressing seed volume. Parameters such as max. deformation and energy were measured. The results which were statistically significant at ($P < 0.05$) show that rape seed with lower deformation values utilized greater energy than the seeds of jatropha and sunflower which obtained higher deformation values in that order of magnitude. The energy (J) was determined by the area under the force-deformation curve while deformation (mm) was obtained directly from the compression test. Based on the statistical analysis, the energy and deformation with respect to the different pressing seed volume of jatropha, sunflower and rape approximately showed linear relationship.

Keywords: force-deformation curve; pressing seed volume; jatropha; sunflower; rape seeds

Oilseed crops such as jatropha (*Jatropha curcas* L.) (Karaj, Müller 2009), sunflower (*Helianthus annuus* L.) (Gupta, Das 2000), rape (*Brassica napus* L.) (Izli et al. 2009) and others are mainly grown for the oil contained in the seeds. However, understanding the shape of the deformation characteristic of oilseeds under compression loading is relevant for determining the compressive force, strain energy and modulus of elasticity in compression (Herák et al. 2010). Also, the amount of force and energy required to produce a given amount of deformation can be used to study the damage which occurs during harvesting and handling of the materials. Such knowledge often gives the understanding into the specific situations that result to failure and how such failure can be prevented (Stroshine, Hamann 1994). Several research works on the mechanical behaviour of oilseeds such as sunflower, rape and others are available according to literature (Gupta, Das 2000; Izli et al. 2009). But compared to *Jatropha curcas* L. seeds, this information is very limited. The aim of this study was to examine and to compare the amounts of deformation and energy requirement of *Jatropha curcas* L. seeds to that of sunflower and rape seeds under compression loading.

MATERIAL AND METHODS

Compression test and parameters calculated. The seeds of jatropha, sunflower and rape of initial moisture content 9.08 ± 4.54% wet basis (w.b.),

Table 1. Measured parameters of the compression test of jatropha, sunflower and rape seeds. Data for deformation and energy are means (± SD)

Pressing seed height (mm)	Maximum deformation (mm)	Deformation energy (J)	Seed volume before pressing × 10^{-4} (m^3)
	15.19 ± 0.02[a]	225.83 ± 1.14[a]	
20	8.15 ± 0.07[b]	197.98 ± 2.69[b]	0.82
	7.15 ± 0.03[c]	217.30 ± 3.18[c]	
	21.06 ± 0.86[a]	307.03 ± 3.10[a]	
30	18.53 ± 0.08[b]	318.49 ± 4.80[b]	1.23
	13.12 ± 0.04[c]	342.94 ± 3.92[c]	
	28.50 ± 1.79[a]	368.04 ± 3.25[a]	
40	21.41 ± 0.01[b]	355.17 ± 1.26[b]	1.64
	15.29 ± 0.07[c]	380.60 ± 5.04[c]	
	35.74 ± 0.47[a]	432.67 ± 6.32[a]	
50	27.15 ± 0.08[b]	433.45 ± 4.37[b]	2.04
	18.87 ± 0.09[c]	496.29 ± 4.69[c]	
	41.97 ± 0.05[a]	509.66 ± 4.32[a]	
60	32.47 ± 0.17[b]	492.72 ± 7.7 2[b]	2.45
	23.72 ± 0.21[c]	559.03 ± 4.58[c]	
	47.14 ± 0.19[a]	586.79 ± 6.32[a]	
70	37.43 ± 0.30[b]	538.93 ± 5.63[b]	2.86
	28.89 ± 0.55[c]	703.58 ± 5.53[c]	
	52.79 ± 0.16[a]	639.45 ± 6.09[a]	
80	43.72 ± 0.10[b]	627.78 ± 6.44b	3.27
	33.23 ± 0.17[c]	753.83 ± 5.24[c]	

[a] jatropha, [b] sunflower, [c] rape, SD – standard deviation

12.25 ± 6.25% (w.b.) and 11.11 ± 5.56% (w.b.), respectively were compressed using ZDM 50-2313/56/18 (VEB, Dresden, Germany) and pressing vessel of diameter 72 mm (Kabutey et al. 2011). The various seeds measured at height (H) 20, 30, 40, 50, 60, 70 and 80 mm were compressed under laboratory temperature of 20°C and a pressing rate (v) of 1 mm/s. The force-deformation characteristic curves obtained directly from the compression test were further processed using the Engauge Digitizer 4.1 software (Mark Mitchell, Boston, USA) and Microsoft Excel to measure the deformation and energy, respectively. The volume of seeds before pressing (Table 1) was calculated based on the area of the pressing vessel multiplied by height of seeds in the pressing vessel or in some cases the amounts of deformation (Kabutey et al. 2011; Herák et al. 2012). The compression test was repeated three times and averaged values were used in all calculations. Also the results obtained were interpreted using the Statistica Software v. 4.1 (Mark Mitchell, Boston, USA).

RESULTS AND DISCUSSION

The results from the compression loading test presented in Table 1 show that deformation energy and max. deformation respectively of the various seeds in relation to different pressing seed volume is ap-

Table 2. Statistical analysis of the measured parameters of the various seeds.

Parameter	Oilseed	Equation	R^2	F	$p <$
Deformation energy (J)	jatropha	$y = 208.39x$	0.994	3,550	0.05
	sunflower	$y = 201.18x$	0.993	2,850	0.05
	rape	$y = 238.37x$	0.997	7,700	0.05
Maximum deformation (mm)	jatropha	$y = 16.76x$	0.999	13,500	0.05
	sunflower	$y = 13.26x$	0.998	9,200	0.05
	rape	$y = 9.98x$	0.998	10,900	0.05

x – volume of seed before pressing; y – energy and deformation, respectively

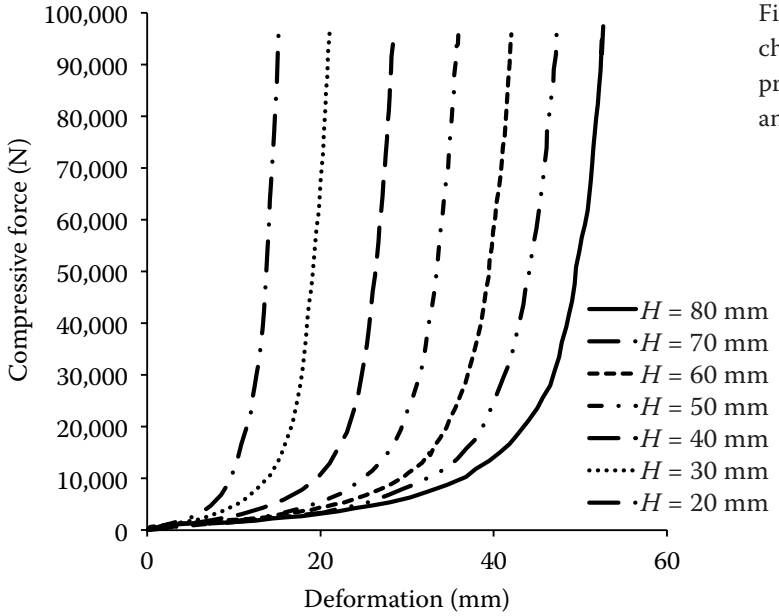

Fig. 1. Compressive force and deformation characteristics of jatropha seeds of different pressing height or volume similar to sunflower and rape seeds

proximately linear from the statistical analysis presented in Table 2. Mathematically, in compression loading experiments, the linear regression function found in this study for determining the deformation and energy in relation to volume of jatropha, sunflower and rape seeds of initial moisture content agree with the relationship between compressive force and deformation Eqs reported by (Herák et al. 2010, 2011a, b). Also the force-deformation characteristics displayed by the different seeds confirm the tangent curve Eq. established by (Herák et al. 2011a, b) for describing the deformation characteristics of mixtures under compression loading. From the results obtained, the deformation values clearly show that apart from the dependency between pressing force and max. deformation (Gupta, Das. 2000), there is also relationship between the size of seed material and max. deformation.

That is the bigger the seed the larger the deformation and *vice versa*. Figure 1 shows the dependency between compressive force and deformation of jatropha seeds in relation to pressing seed volume which was similar to that of sunflower and rape seeds. Also from the results shown in Table 1, increasing the volume of seeds in the pressing vessel obviously increased the seed deformation and energy. And the ratio of the deformation energy to that of the seed volume before pressing shows the toughness (J/m^3) of the seed (Chakespari et al. 2010) or the volume energy (Herák et al. 2010, 2011a, b) which explains the work required to cause rupture in the seed. The results from this study focused only on the initial moisture content of jatropha, sunflower and rape seed. However, the literature reveals that the seed moisture content has a positive effect on deformation and energy (Gupta, Das et al. 2000; Burubai et al. 2007).

CONCLUSION

The seeds of jatropha, sunflower and rape under the compression loading test showed that the size of the seed material has no influence on the deformation energy, rather it has positive effect on max. deformation. Among the seeds, rape seed which is smaller in size absorbed the highest energy compared to jatropha and sunflower seeds which are bigger in size in that order. This indicates clearly that some seeds with smaller surface may require higher energy during the process of deformation than seeds with bigger surface. Therefore the amount of compressive force and energy needed to produce a given amount of deformation may vary extensively among different oilseeds as reported by (Stroshine, Hamman 1994).

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Received for publication February 22, 2011
Accepted after corrections November 8, 2011

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