Comparison of the mechanical behaviour of selected oilseeds under compression loading

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Introduction

Recently, the most widely used crops for oil production for human consumption or as a biodiesel feedstock are

- rapeseeds (*Brassica napus* L.)

- sunflower (*Helianthus annus* L.)
- jatropha (*Jatropha curcas* L.)

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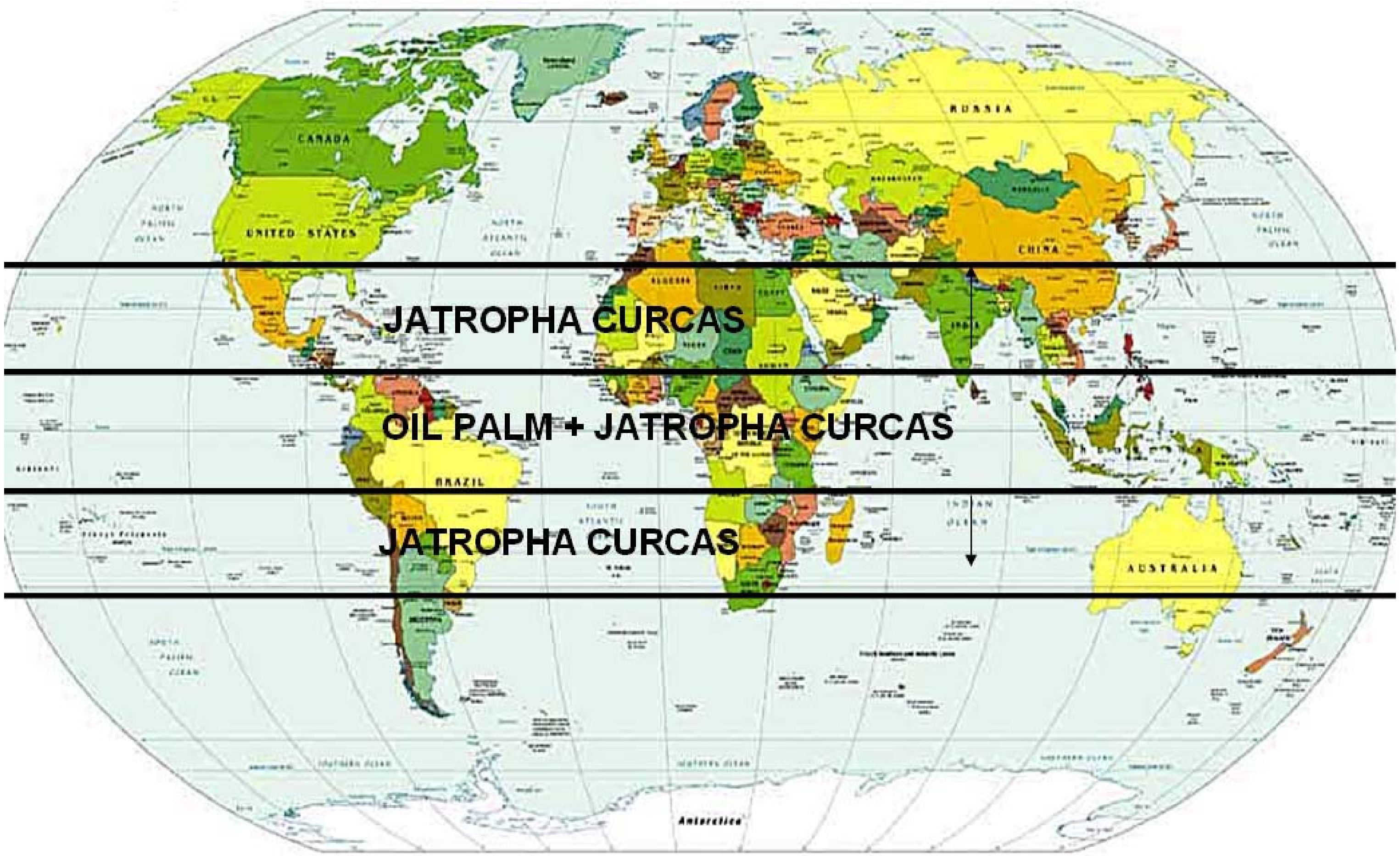
Introduction

World map with presence of *Jatropha curcas*



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Jatropha curcas

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In the literature, considerable information about the mechanical behaviour of rapeseed (Izli, 2009), (Unal 2009), (Rusinek, 2007); sunflower seed (Isik, 2007), (Perez, 2007), (Gupta, 2000) and jatropha seed (Sirisomboon, 2007), (Karaj, 2010), (Herak, 2010) have been focused on rupture force and deformation characteristics (Mrema, 1985), (Fomin, 1978), (Kabutey, 2011), (Koegel, 1973), (Herak, 2011) unlike mathematical description of the deformation characteristics, limit deformation ratio, maximal deformation ratio, energy ratio and oil point deformation ratio.

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On the other hand, oil point determination is an important parameter in oilseed processing. Considering rapeseed, sunflower seed and jatropha seed, not much studies (Faborode, 1996), (Herak, 2010), (Figuerido, 2011) highlights the oil point determination under compression loading. Also to design pressing technology with minimum energy efficiency with respect to maximum oil output, it is important to understand in detail the mechanical behaviour of seeds pressed mixture under compression loading (Fomin, 1978), (Blahovec, 1980).

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This study investigated the mechanical behaviour of rapeseeds, jatropha and sunflower seeds under compression loading in terms of deformation, compressive force and deformation energy. Also the study derived the mathematical equations for determining limit deformation, maximal deformation ratio, energy ratio and oil point deformation ratio of the selected oilseeds.

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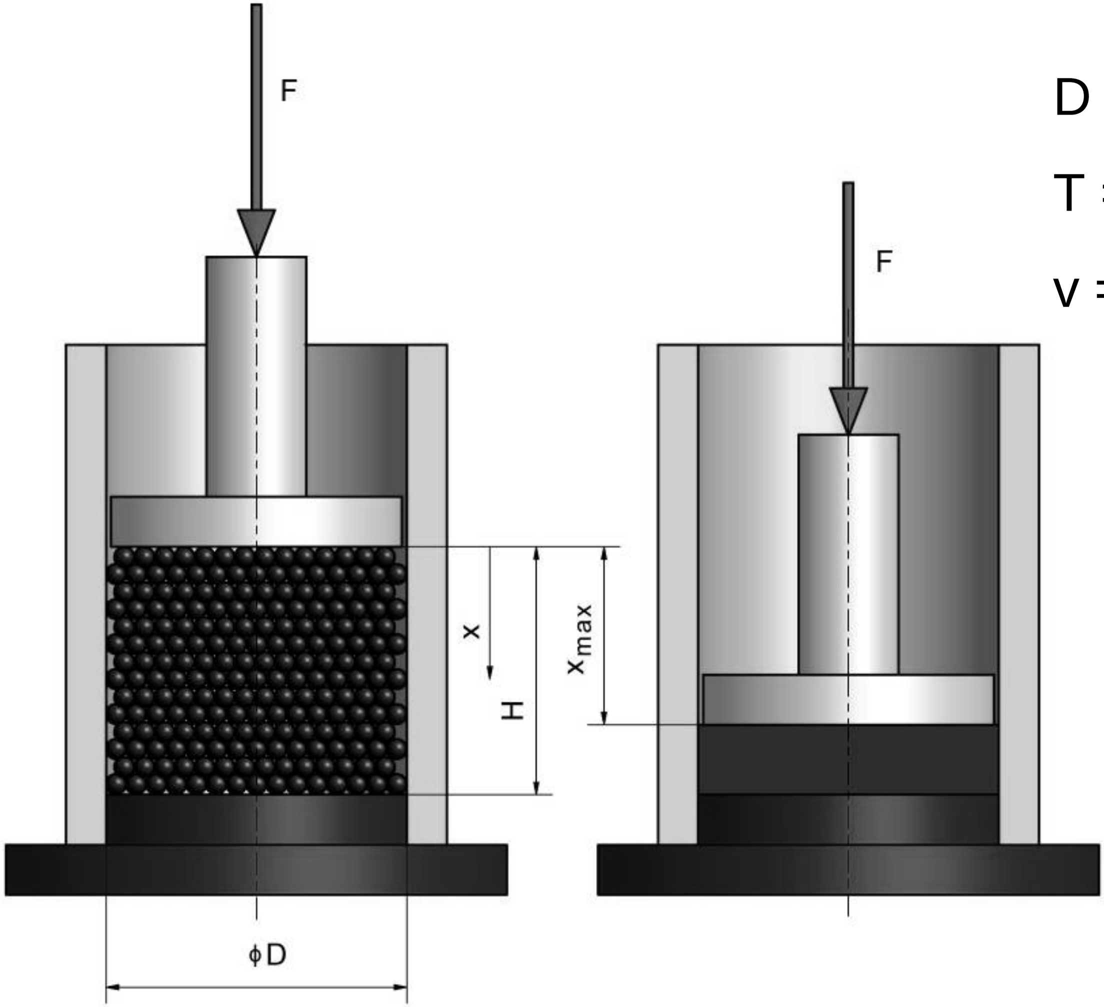
Material and methods



Compression device ZDM 50

D = 100 mm, H = 80 mm,

T = 20 °C, F = 0 kN – 250 kN,

v = 1 mm/s

The pressing vessel has 16 holes at the bottom of diameter 3.5 mm where the oil passes

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Material and methods

- **Oil point**

  The oil point position **x_o (mm), F_o (N)** on the pressing force-deformation curve that is the first leakage of oil from the pressing vessel was determined optically during the compression test.

- **Maximal deformation**

  Maximal deformation **x_{max} (mm)** is the deformation in which the experiment was stopped. It means the maximal deformation directly corresponds to the maximal compressive force.

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Material and methods

- **Maximal deformation energy and energy at oil point**

  These energy **E (J)** and **E_o (J)** values were measured as the area under the com-pressive force-deformation curve from the zero deformation to maximum deformation with respect to the maximum compressive force. Mathematically, the energies were calculated based on the software Engauge Digitizer 4.1 (Mark Mitchell, NY, USA) which measures all points on the curve with respect to compressive force and maxi-mum deformation values.

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Material and methods

- **Theoretical limit deformation δ (mm)**

  The measured dependency between compressive force and deformation can be fitted by tangent curve

$$F(x) = A \cdot [\tan(B \cdot x)]^n$$

- Where F(x) (N) is compressive force, x (mm) is deformation of mixture under compression loading, A (N) is force coefficient of mechanical behaviour, B (mm-1) is deformation coefficient of mechanical behaviour and n (-) is exponent of the pressing function

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Material and methods

- Solving the previous equation for compressive force approaching to the infinity it is possible to obtain equation for limit deformation expressed by deformation coefficient of mechanical behaviour.

$$x = \frac{1}{B}\arctan\left(\sqrt[n]{\frac{F(x)}{A}}\right)$$

$$\delta = \lim_{F(x)\to\infty} x = \frac{\pi}{2 \cdot B}$$

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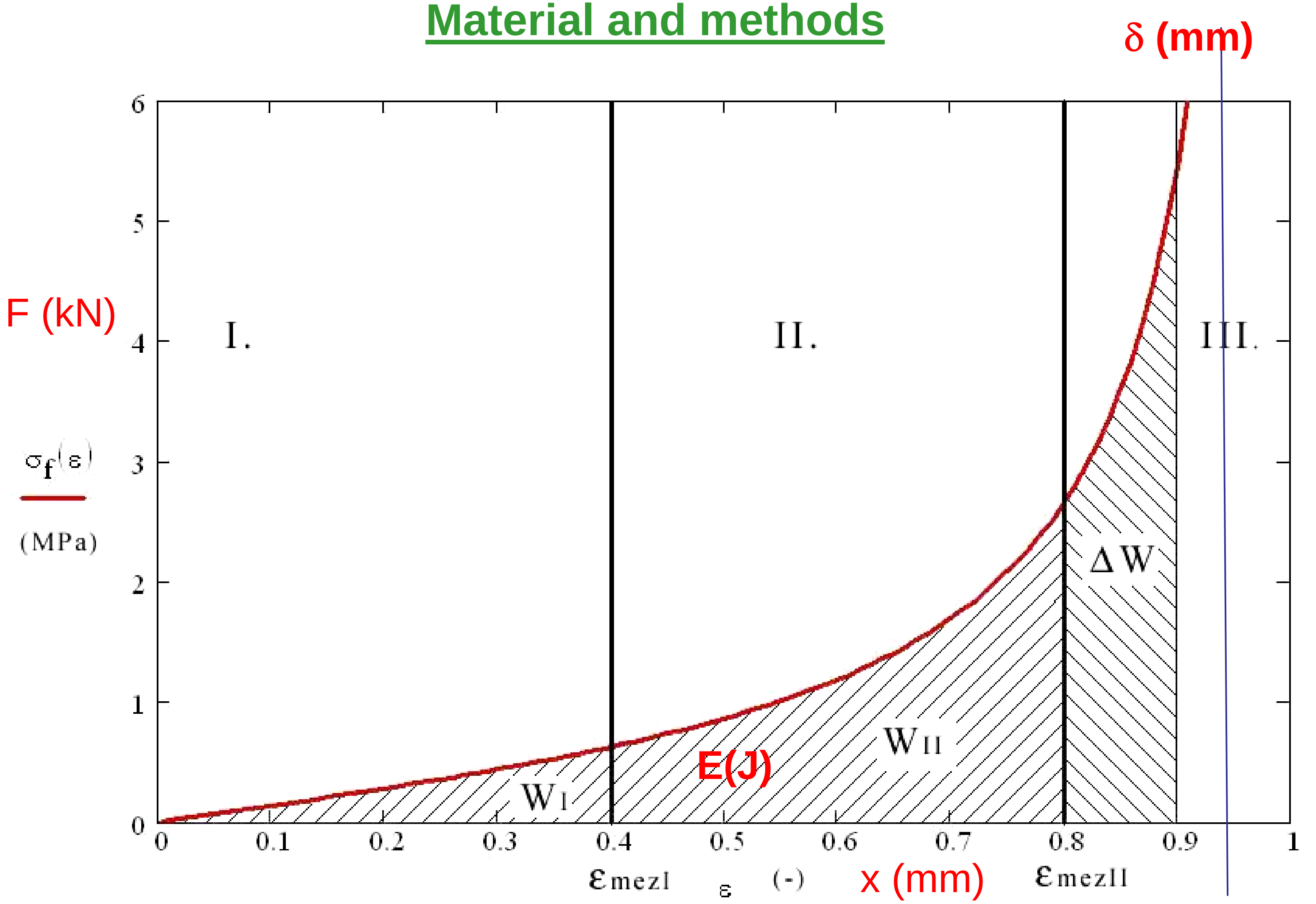
Material and methods



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Material and methods

- **Oil point deformation ratio**

$$R_{OP} = \frac{x_o}{\delta} \cdot 100$$

- **Maximal deformation ratio**

$$R_{MD} = \frac{x_{max}}{\delta} \cdot 100$$

- **Energy ratio**

$$R_E = \frac{E_o}{E} \cdot 100$$

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Results and discussion

Crops seeds	ρ_t ($kg \cdot m^{-3}$)	ρ_b ($kg \cdot m^{-3}$)	m (g)	M_c (% d.b.)	P_f (%)
Rapeseeds	1080 ± 2	716 ± 4	449.75 ± 1.12	6.8 ± 0.1	33.7 ± 0.5
Sunflower	885 ± 3	449 ± 4	282.25 ± 0.96	6.2 ± 0.2	49.2 ± 0.6
Jatropha	971 ± 3	386 ± 5	242.25 ± 1.01	5.7 ± 0.1	60.9 ± 0.6

ρ_t – true density, ρ_b – bulk density, m – mass of pressed mixture,
M_c – moisture content of the pressed mixture in dry basis,
P_f – porosity of pressed mixture

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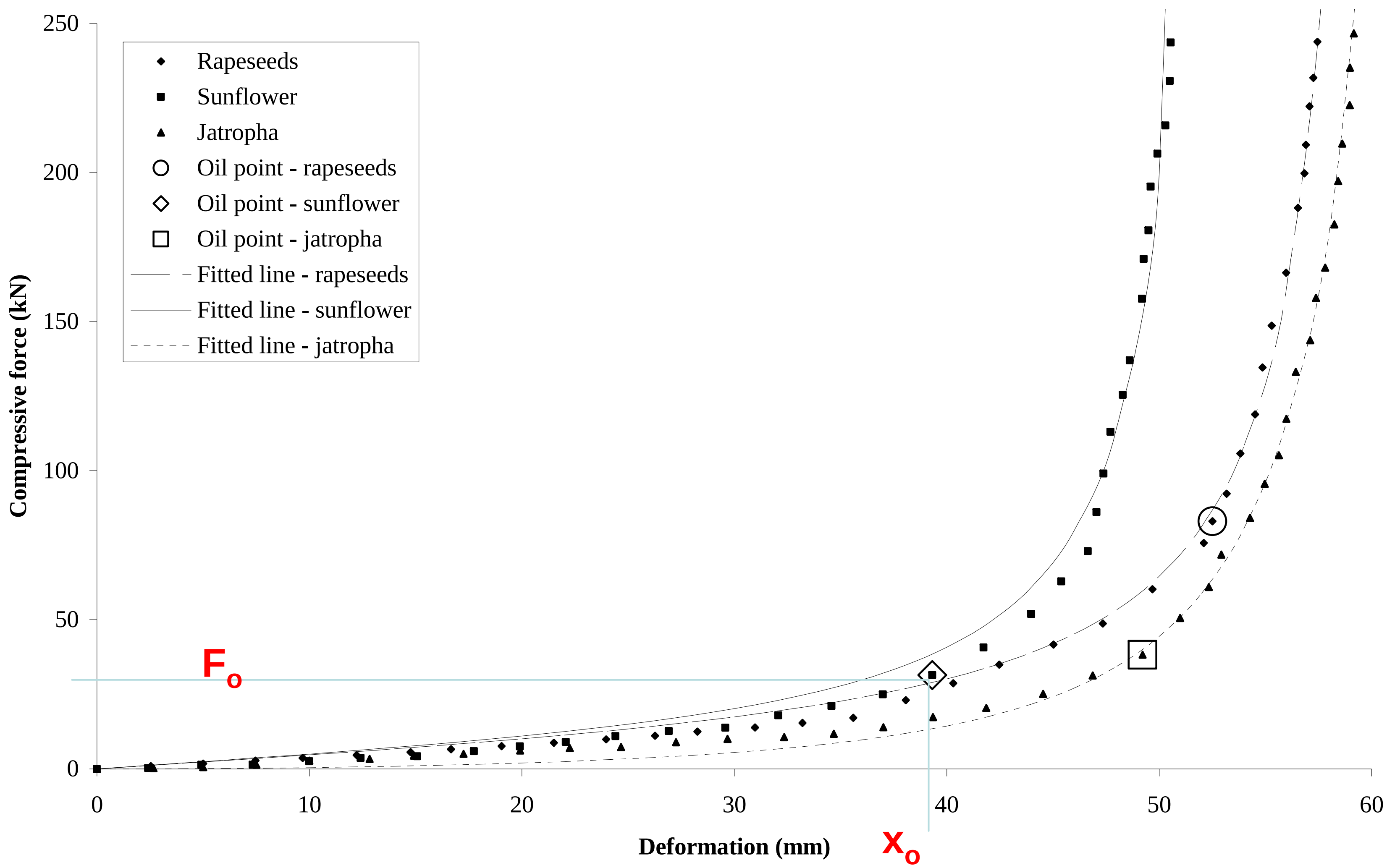
Results and discussion



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Results and discussion

Oilseeds	x_{max} (mm)	x_o (mm)	δ (mm)	E_o (J)	E (J)
Rape	57.5 ± 1.2	52.5 ± 0.7	60.1 ± 0.55	811 ± 15	1519 ± 25
Sunflower	50.6 ± 1.0	39.3 ± 0.8	52.7 ± 0.83	372 ± 20	1294 ± 28
Jatropha	59.2 ± 1.8	49.2 ± 1.0	66.5 ± 1.10	505 ± 27	1506 ± 27

x_{max} – true deformation, x_o- deformation at oil point, δ – limit deformation,
F_o – compressive force at oil point,
E_o – deformation energy at oil point, E – maximal deformation energy

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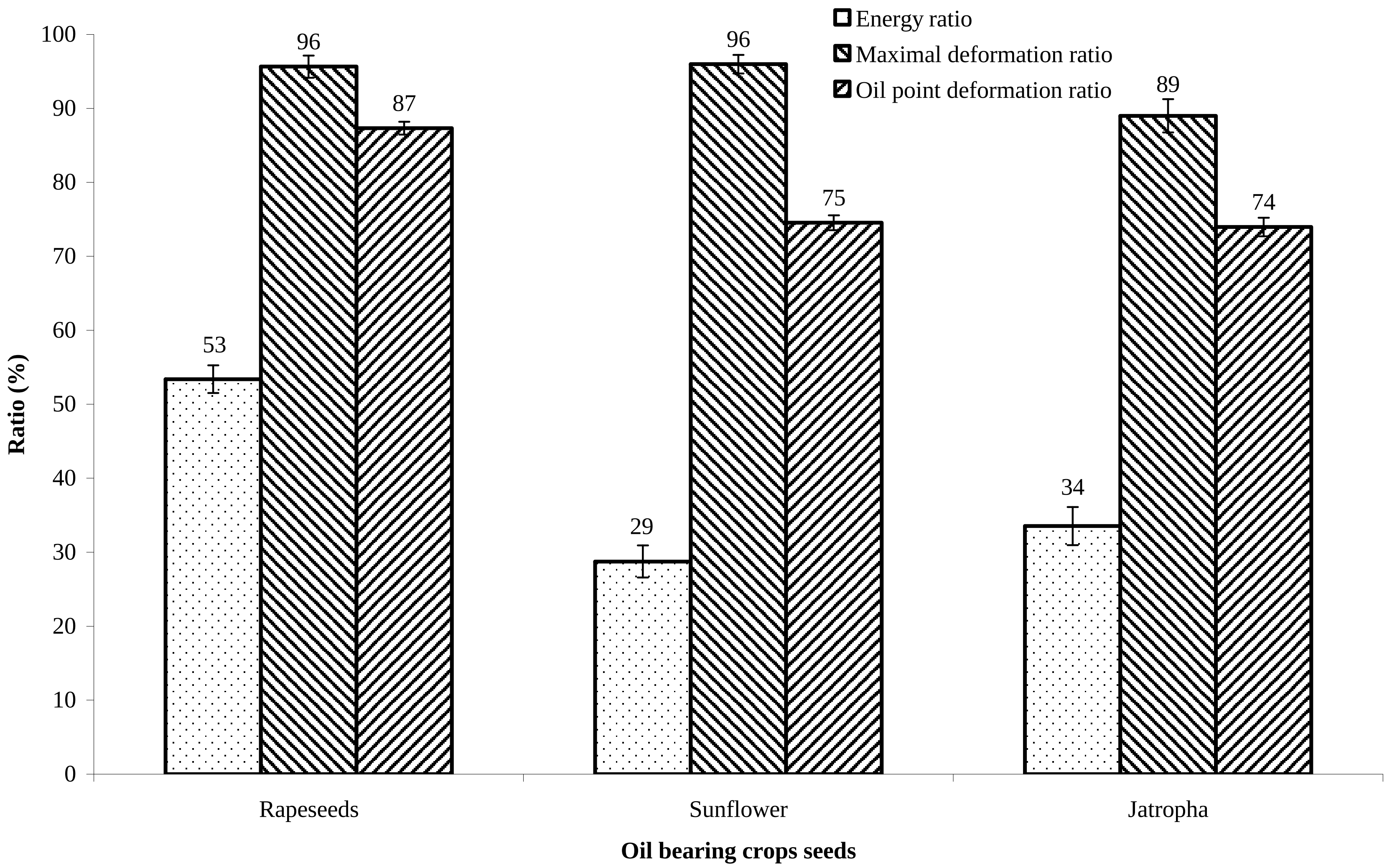
Results and discussion



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Conclusion

- The compression experiment on the mechanical behaviour of oil bearing crops namely rape seeds (*Brassica napus* L.), sunflower seeds (*Helianthus annus* L.) and jatropha seeds (*Jatropha curcas* L.) under compression loading was investigated.
- Among the oilseed crops, rapeseed obtained the greatest amount of deformation energy followed by jatropha and then sunflower. Their respective deformation energy amounts showed the energy requirement for obtaining the oil.
- The tangent curve equation having been established in previous studies described accurately the deformation characteristics of the selected oilseeds.

Thank you for your attention