AN EVALUATION OF THE MECHANICAL PROPERTIES AND THE SUSCEPTIBILITY TO DAMAGE OF WINTER RAPE SEEDS

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Mechanical damage to rape seeds, occuring during the harvest, transportation, cleaning, drying, and storage, determine the quality of the material, and therefore also the quality of rape seed oil. The kind and character of the damage depend on the present physical status of the seeds, this being determined by numerous external and internal factors. The so far conducted experiments have shown that it is possible to characterize and also to give a mathematical description of significant physical parameters of seeds (Davison et al., 1975, 1979). Hence, the objective of the present study is to assess the fundamental mechanical properties of winter rape seeds, including certain factors affecting the variability of the properties and the susceptibility of the seeds to damage.

MATERIAL AND METHOD

The basic strength characterization of rape seeds comprised 26 rape varieties from regionization experiments carried out at Experimental Station for Variety Evaluation in Zadąbrowie, with the varieties involved in the characterization originating from various countries. First, the characterization involved the determination of the seed size distribution, fractioning the samples at every 0.1 mm. On this basis the mean size of seeds in each of the varieties was calculated, assuming seed diameter is the characteristic feature. For strength determinations, air-dry seeds (9 % moisture) 2 mm thick were chosen as comparable for all the varieties. To determine the effect of differentiated seed sizes on the strength of the seeds, 10 size fractions (1.5 to 2.4 mm) of a single variety (Jet Neuf) were examined, and to assess the effect of moisture , Jet Neuf seeds of 8 different moisture levels (from 10.0 to 26.0 %, at every 2.0 %) were studied.

The strength measurements of single seeds were carried out on an Instron model 1253 apparatus, compressing the seeds between two plates, using equipment appropriate to the tests. The graphs obtained were used to determine the course of changes and the values of force within the limit of elasticity of the seeds (F_s), as well as the extent of seed deformation (Δl_s). The same parameters were also determined for the maximum force value (F_{max}) and the associated deformation (Δl_{max}). The bahaviour of rape seeds layer under controlled load was characterized through the description of the process of relaxation in the Jet Neuf variety. In this case the samples used were of three levels of moisture (12.9, 14.0, and 16.0 %), and three levels of load were applied (2, 4, and 6 MPa). The course of the relaxation process was described by means of the three-parameter Poynting-Thompson model, this being chosen as the simplest, as well as being a universal model describing the basic visco-elastic phenomena (Fig. 1).

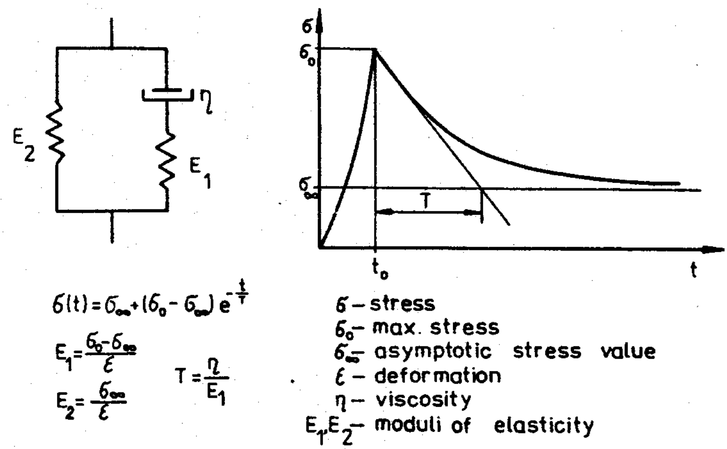

Fig. 1. The Poynting-Thompson visco-elastic model.

RESULTS

The seed size distribution and the mean values calculated demonstrated a considerable differentation among the various varieties (Fig. 2; Table 1). In all the varieties, the seed thickness fell within the size range of from 1.4 to 2.7 mm, and the distributions assumed various forms, which was related to the varying percentage content in successive size fractions. The mean seed thicknees comprised a range from 1.83 to 2.12 mm. The varieties of the highest quality seeds included the Jantar, Lirakotta, Doral, and Jet Neuf varieties. The smallest seeds were those of the BOH 183, BOH 384, and the Santana varieties.

The resistance of seeds to static loads (Table 2) within the range of linear elasticity comprised a range from 9.7 N (Doral variety) to 14.0 N (Lirabon), while deformations accompanying the loads fell within a range from 18 % (Jupiter) to 30 % (Ligrandor). Higher values were observed when assessing the maximum force causing the total destruction of seed structure (from 15.1 N to 17.5 N with deformations from 30.0 to 52.0 %).

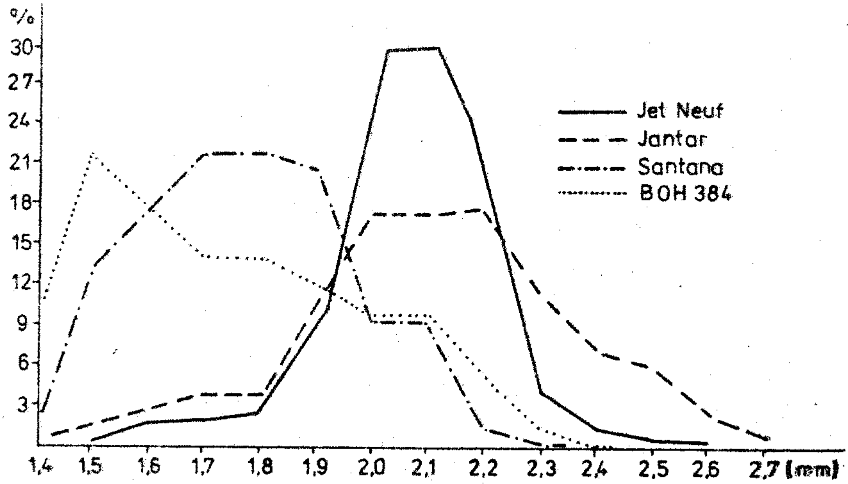

Fig. 2. Examples of rape seed size distribution.

The varied seed size (Jet Neuf variety) affected also the value of force within the elastic range (from 11.8 to 16.6 N), as well as the value of the maximum force (from 12.9 to 19.2 N) - Table 3.

The strongest effect, however, was that of moisture on the resistance of seeds to mechanical load. With increasing moisture, the force value decreased, and the deformation increased. Seeds of moisture values above 20 % became plastic and subject to permanent deformation. Adopting a ratio of the force within the limit of elasticity (F_s) to the deformation observed (Δl_s), as a function of moisture, we can get a clear presentation of the changes in seed elasticity resulting from moisture (Fig. 3).

The relaxation tests carried out on Jet Neuf seeds layer showed a considerable relation of the constant in the Poynting-Thompson model to the stress applied and to seed moisture (Table 4). With increasing moisture, the deformation increases irrespective of the stress levels adopted. Absolute strain values are much higher at greater stress, which is related to the permanent deformation of seeds. The time constant changes with moisture and stress, and the E_1 and E_2 moduli of elasticity decrease considerably. Increasing seed moisture results also in a decrease in the visco-elastic component of total stress ($\sigma_0 - \sigma_\infty$). The behaviour of a layer of rape seeds in the process of relaxation is an index of physical changes that are often observed in practice.

Table 1. Values characterizing the size of rape seeds

No.	Variety	Mean value (mm)	Variability coefficient (%)	No.	Variety	Mean value (mm)	Variability coefficient (%)
1.	Belinda	1.99	13.1	14.	Licantara	2.06	13.2
2.	Beryl	2.01	12.1	15.	Liglandor	1.94	12.5
3.	Bienvenu	1.90	11.7	16.	Lindora	1.97	13.1
4.	BOH 183	1.83	13.6	17.	Lirabon	2.05	11.6
5.	BOH 384	1.84	15.8	18.	Lirakotta	2.09	11.7
6.	BRH 284	2.05	13.3	19.	Liropa	2.06	14.6
7.	Darmor	1.93	14.2	20.	Marinus	1.93	11.8
8.	Doral	2.07	12.5	21.	Mirander	1.98	13.4
9.	Gundula	1.95	14.1	22.	Ridana	1.99	13.8
10.	Jantar	2.12	13.7	23.	Rubin	1.91	13.0
11.	Jet Neuf	2.06	11.0	24.	Santana	1.85	14.2
12.	Jupiter	1.99	14.9	25.	Tandem	1.94	13.7
13.	Korina	1.96	11.9	26.	Tamara	1.97	13.5

Table 2. Mean values characterizing the resistance of single seeds of rape to static load

No. of var.	F_s (N)	Δl_s (mm)	F_{max} (N)	Δl_{max} (mm)	No. of var.	F_s (N)	Δl_s (mm)	F_{max} (N)	Δl_{max} (mm)
1	13.1	0.46	16.5	0.69	14	10.5	0.41	16.4	1.01
2	12.1	0.40	15.2	0.61	15	13.1	0.59	15.1	0.81
3	13.1	0.48	17.3	0.86	16	13.7	0.55	16.3	0.79
4	13.3	0.52	15.6	0.76	17	14.0	0.51	17.0	0.77
5	12.5	0.40	15.6	0.59	18	11.5	0.47	16.3	0.86
6	11.3	0.40	16.3	0.69	19	12.4	0.42	16.1	0.68
7	13.9	0.51	17.1	0.75	20	13.6	0.44	17.3	0.68
8	9.7	0.53	15.9	1.04	21	11.5	0.41	16.0	0.69
9	13.8	0.48	16.5	0.72	22	13.9	0.54	16.0	0.77
10	12.9	0.47	15.5	0.68	23	11.2	0.56	16.8	1.04
11	13.6	0.44	16.4	0.63	24	13.5	0.48	16.8	0.68
12	11.5	0.36	16.9	0.65	25	11.5	0.49	17.5	1.04
13	13.8	0.55	17.0	0.88	26	11.8	0.40	16.1	0.72

The smallest significant difference (P=0.05) 1.2 0.07 1.2 0.13

Table 3. The relation between the resistance to load and the size of Jet Neuf rape seeds

Fraction (mm)	F_s (N)	Δl_s (mm)	F_{max} (N)	Δl_{max} (mm)	Fraction (mm)	F_s (N)	Δl_s (mm)	F_{max} (N)	Δl_{max} (mm)
1.5	11.8	0.50	12.9	0.58	2.0	13.9	0.55	14.9	0.69
1.6	12.1	0.53	13.6	0.63	2.1	14.8	0.57	16.2	0.72
1.7	13.5	0.49	14.8	0.59	2.2	15.3	0.56	17.7	0.70
1.8	13.8	0.52	14.9	0.66	2.3	15.7	0.59	18.5	0.81
1.9	14.2	0.53	15.7	0.65	2.4	16.6	0.59	19.2	0.83
The smallest significant difference (P=0.05)					-	2.3	-	2.3	0.18

Table 4. The relation between the constants in the Poynting-Thompson model and the stress applied and the moisture of Jet Neuf rape seed samples

Stress (MPa)	Moisture content (%)	Deform. (ε)	σ_∞ (kPa)	$\sigma_0-\sigma_\infty$ (kPa)	Time constant (sec)	E_1 (kPa)	E_2 (kPa)
2	12	0.214	817	594	190	2777	3820
	14	0.257	763	587	204	2284	2969
	16	0.286	796	557	220	1949	2782
4	12	0.296	1646	1237	221	4180	5561
	14	0.304	1644	1200	234	3947	5409
	16	0.341	1727	1151	185	3377	5066
6	12	0.316	2428	1851	229	5858	7685
	14	0.343	2608	1683	212	4908	7604
	16	0.353	2738	1610	231	4563	7756

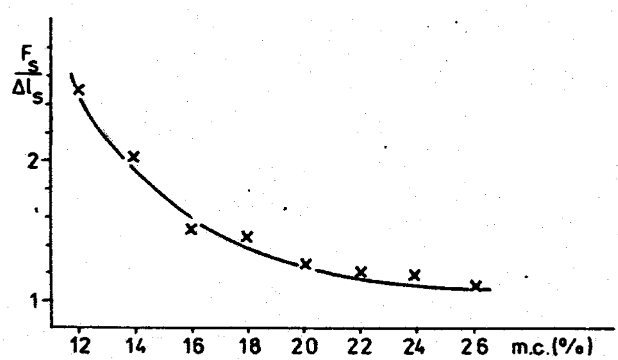

Fig. 3. The resistance of Jet Neuf rape seeds to damage as a function of moisture.

CONCLUSIONS

1. The size of rape seeds, as characterized by their diameter, falls within the range from 1.4 to 2.7 mm, with considerable intervariety differences, which is reflected in the percentages of particular size fractions and in the mean values characteristic of particular varieties.
2. The limit of elasticity of single seeds (air-dry) assumes mean values from 9.7 to 14.0 N, and depends on the variety characteristics. Also differentiated is the value of deformation (18 - 30 %), while the seed destruction force level is 30 % above the limit of elasticity.
3. High quality seeds (large seeds) are more resistant to the effect of force than smaller seeds are. Within the Jet Neuf variety, the differences reached up to 30 %.
4. The strength of single seeds decreases significantly with an increase in their moisture, and their deformation increases together with their moisture.
5. In the process of relaxation of seeds layer, increasing seeds moisture and increasing stress are accompanied by a decrease in the moduli of elasticity and a decrease in the percentage of the visco-elastic component of the total stress in the layer and by an increase in the strain resulting from permanent deformation of seeds.

REFERENCES

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