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MECHANICAL PROPERTIES OF PEA SEED COAT*

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A b s t r a c t. In the present study, the change of shape and the characteristic geometrical values of seed and seed coat at various moisture contents, during seed swelling and drying were determined. A preliminary study was conducted to establish the time required for the strain of seed coat after being dried to final moisture content. The next series of drying tests was conducted to evaluate the effect of different drying condition on the development of stress and strain of pea seed coat. Three air velocities and five temperatures were used as parameters of drying tests. After each 10% loss of weight, the seed's deformations were measured up to the total loss of moisture. The resistance of seed coat to tension was studied for three pea cultivars. This approach is more likely to lead to an understanding of the possible causes and mechanisms that affect the cracking of the seed coat.

K e y w o r d s: pea seed, seed coat, deformation, strain, stress

INTRODUCTION

Pea seed quality is greatly affected by the methods of harvesting and handling. In these operations, seeds are repeatedly subjected to many impacts on metal surfaces and against other seeds. Impacts may result from the threshing cylinder or rotor motion, movement of buckets in vertical elevators, centrifugal discharging, filling and discharging of screw conveyors, spouting and free-fall dropping [13,14]. In almost all handling operations, seeds are accelerated to some velocity and then discharged onto stationary objects or other grains.

Assessment of physical properties of agricultural products is required for the adequate design of processing machines but their specific applications should be clearly understood before they are experimentally determined [11]. The seed modulus of elasticity is a physical property which has been suggested for the evaluation of firmness and hardness [8]. It is also an important property for the determination of the stress cracks in seeds. However, in the study of stress cracking due to drying of cereal grains from about 25 % moisture content to about 14 % moisture content, it is essential to understand the variation of the elasticity modulus in relation to moisture and to utilize its appropriate values at different moisture [6,10].

The major problem in drying of legume seeds with heated air is splitting of the seed coat [7]. Temperature and moisture gradients can cause stresses in the seed coat during drying. Overhults *et al.* [12] observed physical damage in soybeans during drying in the form of indentations and cracks. This condition makes the beans susceptible to microbial attack during storage, and also reduces their germination potential [15]. In view of these problems, there is a need, specially in the legumineous seed industry, to find the optimum combination of drying parameters which will minimize seed coat cracking [9].

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A change in the seed shape during compression caused increase of the surface area surrounding cotyledon [2]. However, changes of the moisture content of seed caused also considerable deformation in its shape [4].

In this study, the change of shape, expressed by the characteristic dimentions as well as the mechanical values of the seed coat at various moisture contents, during swelling and drying were determined. This approach lead to the understanding of possible causes and mechanisms that affect the cracking of the seed coat.

MATERIAL AND METHODS

Three pea seed (*Pisum sativum* L.) cultivars: Sześciotygodniowy, Diament and Meteor were obtained from The Plant Breeding Station. The samples were rewetted to determine the effect of moisture content on the expansion volume of pea seed. The dimensions of pea seed were measured to the nearest 0.01 mm with a digitally micrometer caliper. The subsamples were stored for 3 days at room temperature (20°C). After that, seeds were dried and at each 10% loss of weight, the seed volume changes were measured up to total loss of moisture.

A preliminary study was conducted to establish the time required for the strain of seed coat after being dried to final moisture content. The second series of drying tests was conducted to evaluate the effect of drying parameters on the stress and strain development of the pea seed coat. To evaluate the effect of drying conditions on the splitting of seed coat, the samples were dried with air. The seed coat ring samples were prepared according to the method elaborated by Dobrzański [3]. For this purpose, the seeds were rewetted to a moisture content of 35% (w.b.). At this moisture, pea seeds were smooth with convex shape allowing for an easy cut of the seed coat. A ring of seed coat was cut from the wet seed by parallel blades, avoiding the sprout. Each seed coat sample was put into water for wetting till 70% of moisture content was achieved. The time-strain curves at different drying conditions were obtained with 2630-107 Instron strain gauge (Fig. 1). Three air velocities and four temperatures were used as parameters of drying tests:

- 22°C, 10.5 m/s — 1;
- 22°C, 15.6 m/s — 2;
- 42°C, 4.3 m/s — 3;
- 52°C, 10.5 m/s — 4;
- 62°C, 15.6 m/s — 5.

The moisture content of the seed coat ring decreased from 70% to 2% during drying. The wet ring of seed coat was fixed to parallel cylindrical hooks (Fig. 2). The single test was stopped when the value of strain or force was not changing in time (moisture content 2%).

The influence of drying on the force induced in the seed coat was checked at the same drying parameters. Hooks with the seed coat ring were fixed with the measuring head of the Instron testing machine. The time-force curves were obtained and the values of stress were calculated.

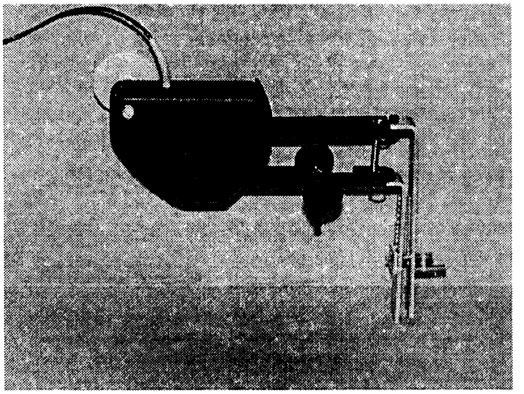

Fig. 1. 2630-107 Instron strain gauge with reversable holders for seed coat ring.

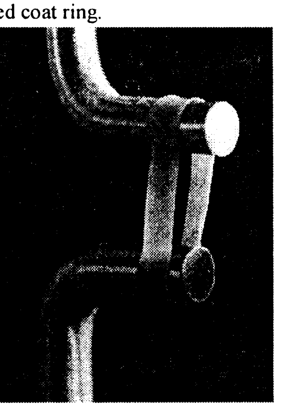

Fig. 2. Seed coat ring on the hooks-holder.

The resistance of seed coat to tension was studied for all the pea seeds at a wide range of moisture. All the data of mechanical parameters such as: deformation, force, work of deformation were collected. The modulus of elasticity was determined at the elastic range of deformation from the force-deformation curve.

RESULTS AND DISCUSSION

The effect of moisture content on expansion volume of pea seed is shown in the experimental results presented in Fig. 3. Seed dimensions increased during swelling for all pea cultivars. More distinctly effects of moisture content on dimensions of pea were observed in the initial phase of swelling. Further seed's filling, leads to the seed coat tensioning till its disruption.

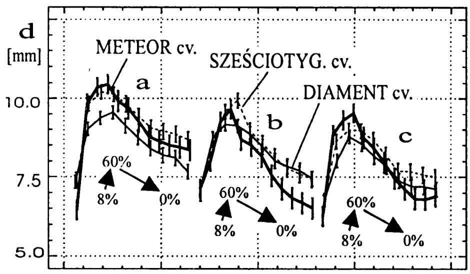

Fig. 3. Characteristic dimentions *d* of pea seed at various moisture contents, during seed swelling (from 8 % to 60 %) and drying (from 60 % to 0 %).

The influence of seedcoat on the rate of weight loss during drying showed that removal of water was limited by the seed coat and the results presented in previous paper [5] proved that this process was not rapid. The moisture content of pea decreased from 60% to 2% after 2 h of drying. All dimensions of seed decreased during the process and exponential relationship was observed (Fig. 4). However, only dimension's *b* and *c* reached similar values as before rewetting. The dimension *a* decreased during drying but volumetric deformation in this case was not at all reversible for most of the peas.

Rapid change of moisture content of the seed coat during drying caused the shrinkage

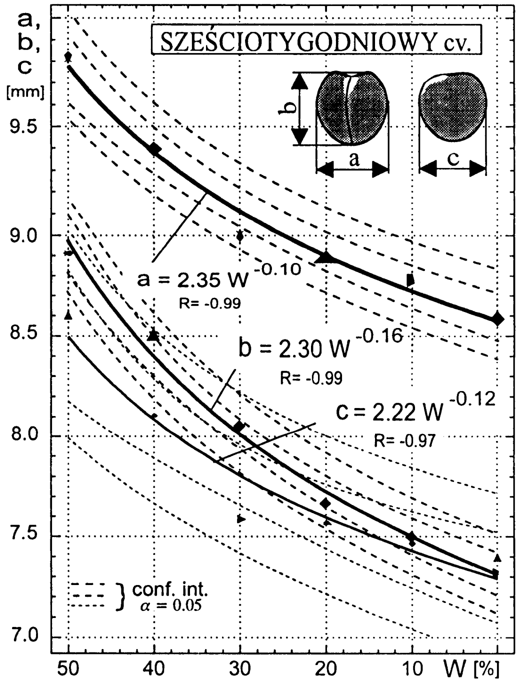

Fig. 4. Shrinkage of dimensions: *a*, *b*, and *c* for Sześciotygodniowy pea seeds during drying (W - moisture content).

of the coat leading its stress. The sample shrinkage for the Sześciotygodniowy cultivar was shown in Fig. 5. The highest shrinkage; 26.3 % for the rudest condition of drying was observed. When the drying conditions were milder, sample shrinking was lower, and for the mildest conditions (22^{o}C at 10.5 m/s of air flow) sample shrinkage was 18.3 %. The shape of force-time curves (Fig. 6) was similar to the shape of strain-time curves. However, the time of 5 min was required to achieve the maximum of force. The value of the force induced by the shrink depended on the drying conditions. The highest temperature at a high rate of air flow affected the greatest values of the force. When these conditions became milder the values of the force were lower. Similar values of strain (Fig. 5) and force (Fig. 6) for smooth peas of Diament cultivar were obtained. The shrinkage of the seed coat for Meteor peas showed values of the same range (Fig. 5). However, the force caused by the shrinkage of the seed coat for the wrinkled pea of Meteor cultivar was lower than the tension resistance of the seed coat (Fig. 6). At all the

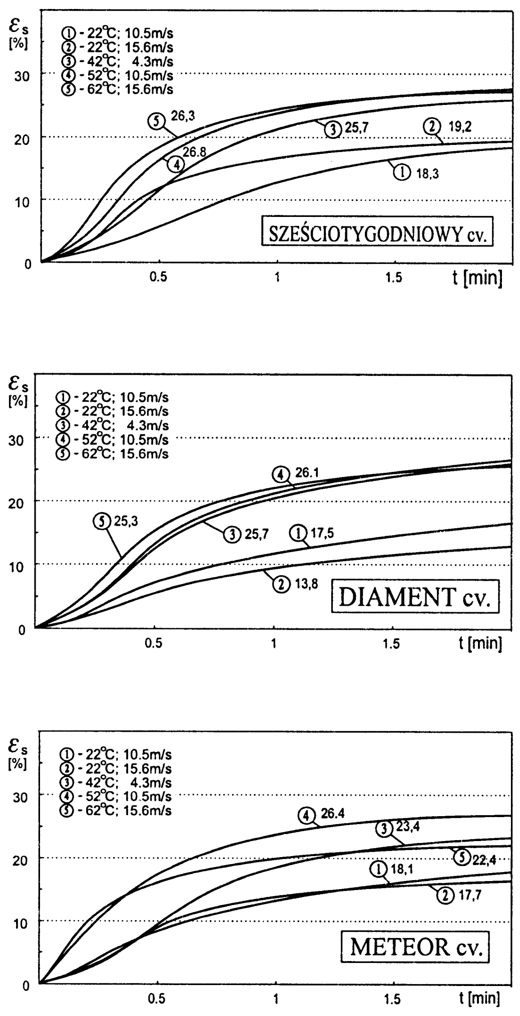

Fig. 5. Shrinkage ε_s of seed coat and it's maximum value during drying at various parameters (1÷5) for Sześciotygodniowy Diament and Meteor pea cultivars.

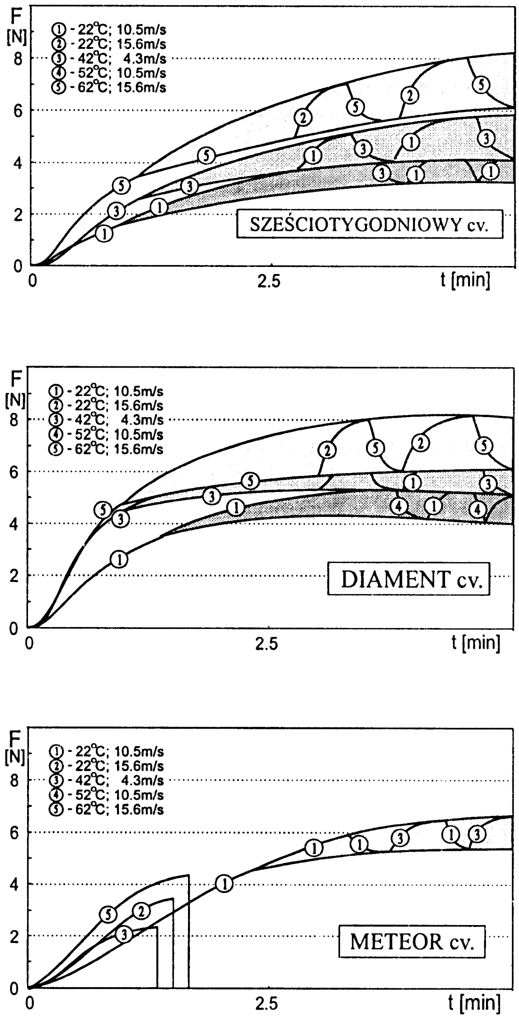

Fig. 6. Force F caused by the shrinkage of seed coat during drying at various parameters (1÷5) for Sześciotygodniowy, Diament and Meteor pea cultivars.

parameters of drying, except the lowest temperature of 22°C, the seed coat breakage was observed.

The temperature changes of the air flow during drying caused an increase of the stress in the seed coat when temperature decreased and coming back to the same level of force when the temperature increased. The seed coat dried at the highest temperature of 62°C involves shrinkage force up to 6 N. After that heating elements are disconnected and cold air drying caused the increase of shrinkage for 25 % more. This phenomenon was observed in both smooth cultivars.

The results obtained at tensioning the seedcoat belt shoved that an increase of the moisture content involves an decrease of the force at breakage. The relation between force and moisture content was showed in Fig. 7 for Sześciotygodniowy, Diament and Meteor cultivars respectively. Cultivar's differentiation in the seed coat strength in tension test was observed. However, modulus of elasticity determined at a small deformation reflected mechanical behavior of seed coat more correctly. Comparable parameters of exponential regression for all the peas (Fig. 8) showed similar mechanical properties of the seed coat for the cultivars studied.

Resuming, the measuring of geometrical changes of seed and seed coat during swelling and drying showed that a decrease of moisture content involves shrinkage and leads to its stress. The results obtained in all the experiments concerning the strength of the seed coat proved that frequently stress was higher than the strength of the seed coat. Probably, it is one of the most important reason of the seed-coat cracking during drying. The rapid decrease of air temperature during drying causing additional shrinkage of the seed coat clarifies the origin of the coat cracking after disconnection of the heating set in dryers, observed in practice.

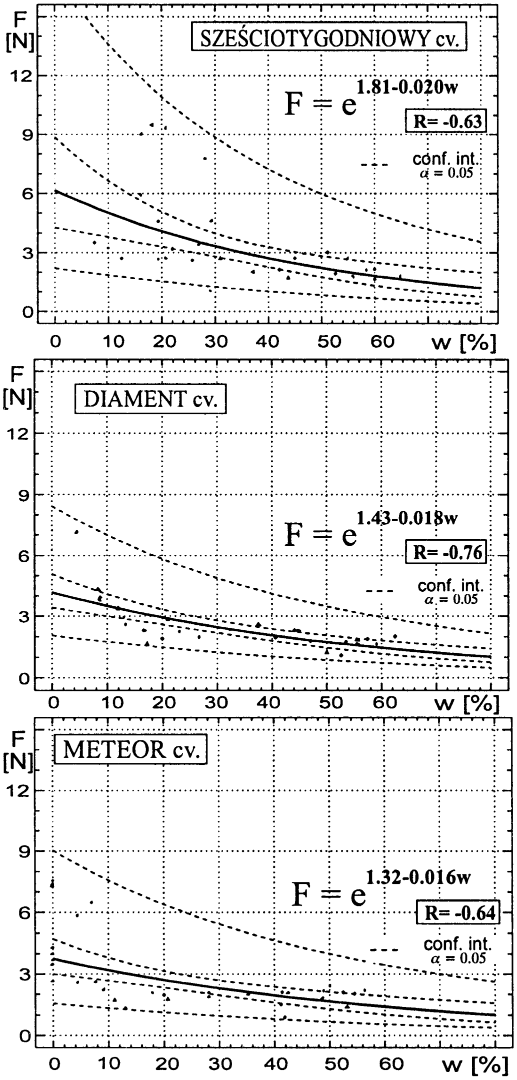

Fig. 7. Tension force of the seed coat belt at brekage for Sześciotygodniowy, Diament and Meteor pea cultivars (W - moisture content).

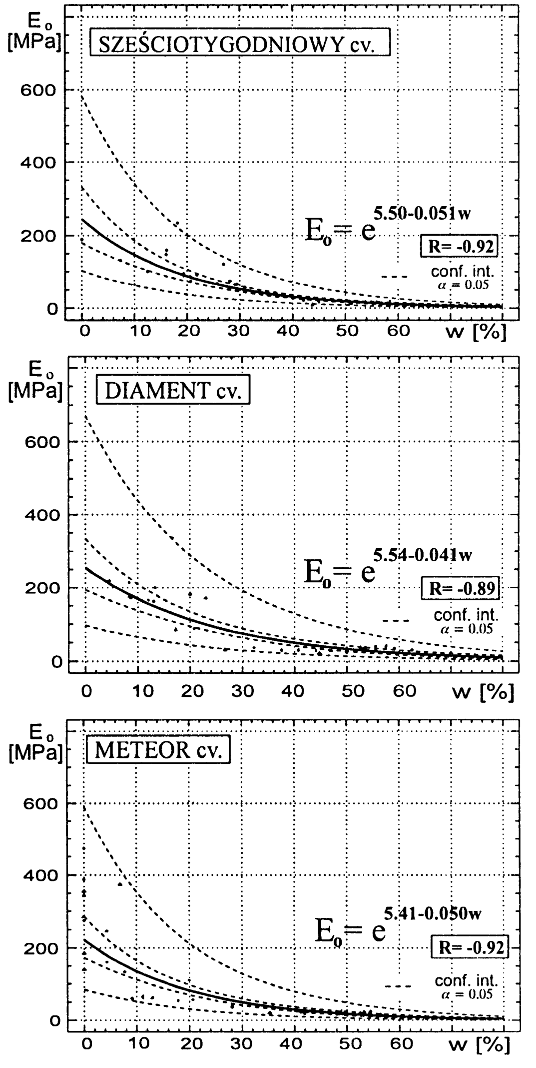

Fig. 8. Modulus of elasticity of seed coat for Sześciotygodniowy, Diament and Meteor pea cultivars (W - moisture content).

On the other hand, in the previous reports concerning the shape deformation of convex seed compressed between parallel plates it [1,2] was indicated that under 30 % of seed strain, there was no stress in the coat. However, for large deformations of non-elastic wet seeds mechanical strength is mainly connected with the resistance of the seed coat to tension.

CONCLUSIONS

1. Distinct effects of moisture on the dimensions of pea seed were observed in the initial phase of swelling. All dimensions of seed decreased during drying, however, volumetric deformation is not at all reversible for most of the peas.

2. Shrinkage of the seed coat ring during drying was higher than 26 % for all the pea seeds. The air temperature seems to be the most influential factor affecting the shrinkage and split of the seed coat. Drying at a high temperature of 62°C involves shrinkage force up to 6 N. The increase of the temperature of air flow during drying caused an increase of stress in the seed coat. Additional increase of the seed coat shrinkage by 25 % was caused by disconnecting heating elements in the dryer.

3. The results obtained at a tension test of the seed coat belt showed that, an increase in the moisture content involves an decrease in the force at breakage. Modulus of elasticity was determined at small deformation and comparable parameters of exponential regression indicated similar mechanical properties of the seed coat for the three pea cultivars tested.

4. Rapid decrease of air temperature during drying and the values of shrinkage stress higher than the strength of the seed coat are the most important reasons of the seed coat cracking during drying.

REFERENCES

1. **Dobrzański B.:** Theoretical model of large deformation of compressed rapeseed. Proc. 8th GCIRC, Saskatoon, Canada, P1-076, 1261-1266, 1991.
2. **Dobrzański B.:** Geometrical dependences of seed shell of compressed pea. Int. Agrophysics, 7(4):259-264, 1993.
3. **Dobrzański B.:** The influence of moisture content on the stress of pea seed coat (in Polish). Dehydratation Industry VIII Symp., Warszawa, 90-95, 1994.
4. **Dobrzański, Jr. B.:** The influence of moisture content on the shape deformation of soybean. AgEng'96, Madrid, Paper 96F-082, 1-7, 1996.
5. **Dobrzański B, Szot B.:** The methods of mechanical properties estimation of pea seed (in Polish). Conf. Mat. "Science for Horticulture Practice", University of Agriculture, Lublin, 641-644, 1995.
6. **Herum F.L., Mensah J.K., Barre H.J., Majidzadech K.:** Visco-elastic behavior of soybeans due to temperature and moisture content. Trans. ASAE 22(5): 1219-1224, 1979.
7. **Liu M., Haghighi K., Stroshine R.L.:** Viscoelastic characterization of the soybean seedcoat. Trans. ASAE 32(3): 946-952, 1989.
8. **Mac Donald, Jr. M.B.:** Physical seed quality of soybean. Seed Sci. Technol. 13: 601-628, 1985.
9. **Mensah J.K., Nelson G.L., Herum F.L., Richard T.G.:** Mechanical properties related to soybean seedcoat cracking during drying. Trans. ASAE, 27(2):550-560, 1984.
10. **Misra R., Young J.H.:** A model for predicting the effect of moisture content on the modulus of elasticity of soybeans. Trans. ASAE 24(5):1338-1341, 1981.
11. **Misra R., Young J.H., Haman D.D.:** Finite element procedures for estimating shrinkage stresses during soybean drying. Trans. ASAE 24(3):751-753, 1981.
12. **Overhults D.G., White H.E., Hamilton H.E., Ross I.J.:** Drying soybeans with heated air. Trans. ASAE 16(1):112-113, 1973.
13. **Palusen M.R., Nave W.R., Gray L.E.:** Soybean seed quality as affected by impact damage. Trans. ASAE 24(6):1577-1582, 1589, 1981.
14. **Palusen M.R., Nave W.R., Mounts T.L., Gray L.E.:** Storability of harvest-damaged soybeans. Trans. ASAE 24(6):1583-1589, 1981.
15. **White G.M., Bridges T.C., Loewer O.J., Ross I.J.:** Seed coat damage in thin-layer drying of soybeans. Trans. ASAE 23(1):224-227, 1980.