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ANALYSIS OF MECHANICAL PROPERTIES OF COMMON ONIONS

Summary

The study investigated the physical properties of onion for purpose of developing a mechanical peel assembly. In addition, tests of cutting force and compressive stresses resulting in onion damage were performed. The results of study constitute the basis for developing a concept of main mechanical peeling assembly, which is responsible for incision of top layer onion and removal of a root and pinch.
***Key words**: onion peeling, cutting force, pressing force, ultimate shearing stress*

ANALIZA WŁAŚCIWOŚCI MECHANICZNYCH CEBULI ZWYCZAJNEJ

Streszczenie

W ramach badań przeprowadzono badania właściwości fizycznych cebuli dla potrzeb opracowania mechanicznego zespołu obierającego. Ponadto wykonano badania siły przecinania oraz naprężeń ściskających wywołujących uszkodzenie cebuli. Wyniki uzyskanych badań stanowią podstawę do opracowania koncepcji głównego elementu wchodzącego w skład mechanicznego zespołu obierającego, który odpowiada za nacięcie wierzchniej warstwy cebuli oraz usunięcie korzenia i szczypioru.
***Słowa kluczowe**: obieranie cebuli, siła nacinania, siła dociskania, niszczące naprężenia ściskające*

1. Introduction

Poland is one of leading vegetable producers in Europe [1]. The great number of consumers are interested in onion which is one of the most popular vegetables - a vegetable of the Amaryllis family, whose purification process is hampered by odor during processing. Technological progress is conducive to improving working conditions during the implementation of various processing activities of vegetable raw materials. It also improves efficiency of production process. The time-consuming process of peeling onion and harmful effect of odor on human body was a common problem.

The need for further machines development for onion peeling process has been important for acquisition of onions physical properties information, taking into account parameters such as cutting force, ultimate shear strength and compressive stresses. The knowledge of value of particular species onion cutting forces would facilitate future design of cutting units and selection of drive components to achieve the required cutting force. The knowledge of value of compressive forces is needed to stabilize the longitudinal and transverse displacement so that the onion is not destroyed. In addition, it is important to know the value of the top layer onion cutting forces to facilitate removal of shell in further technological process. The knowledge of value of forces needed to incision or cutting onion will facilitate the design of cutting units and selection of drive elements to achieve required cutting force. On the other hand, the knowledge of stresses that destroy onions will allow you to adjust power of actors so that when you press the onion with a plate or with a pressure punch, you will not destroy it.

2. Material and methods of research

The research material included different sizes of common onion (Allium cepa L. variety), which were studied in respect of incision force of top layer of onion, onion cutting force and ultimate shearing stress.

The incision and cutting force was identified in 3 different planes of onion surface, illustrated in Figure 1. For each of 20 planes repetitions were performed.

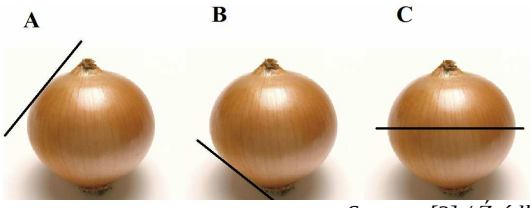

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Fig. 1. Onion incision plane
Rys. 1. Płaszczyzna nacinania cebuli

The researches were performed using a QC-TECH (Testlab) machine equipped with a 2 kN head. The incision used onion cutting unit equipped with a joiner blade mounted at an angle of 45º.The onion on the rubber pad was inclined so that the tangent to the outline of the outer onion was parallel to the blade. The blade was about 5 mm from the onion (Figure 2), while the onion was held by the operator for immobilization.

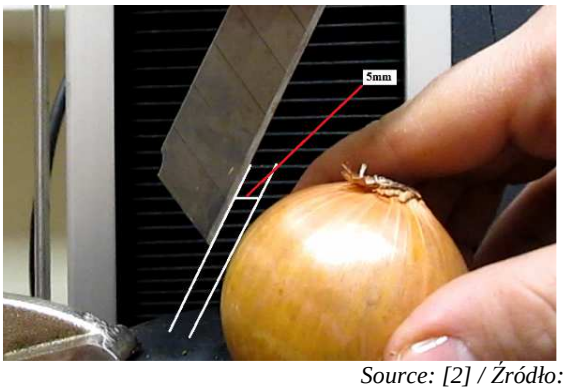

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Fig. 2. Approximate placement of onion
Rys. 2. Orientacyjne ustawienie cebuli

The cutting unit's feed rate was 300 mm · min^{-1}, while displacement 20 mm (Figure 2). With these parameters, the cutting unit cuts the top layer of onion up to a maximum depth of 2 mm. The cutting force study was performed using a knife set perpendicular to onion plane, which was placed in the transverse axis (Figure 3).

Source: [2] / Źródło: [2]

Fig. 3. Placement of onion before cutting
Rys. 3. Ustawienie cebuli przed przecięciem

The onion was placed in a chamber which limited the possibility of rotation during the cutting process. The cutting unit's feed rate was 300 mm · min^{-1}, while the displacement was 80 mm. The research was done for onions with different diameter ranges: 50-60 mm, 60-70 mm and 70-80 mm. In each group 20 bulbs were examined.

Test of the identification of ultimate compression stresses was performed by placing the onion on a support sleeve with an internal diameter of 20 mm (outer diameter 40 mm) and pressing a pressure punch with a diameter of 9.5 mm. The study consisted of pressing onion into support sleeve using a pressure punch until its structure was destroyed, ie. the moment of sudden drop of the pressure value. The tests were performed in 20 replicates, with the punch pressure for each sample being exerted in 3 onion areas (Figure 4):

- in the area of occurrence of the pinnacle (area A),
- in the root zone (area B),
- in the central part (area C).

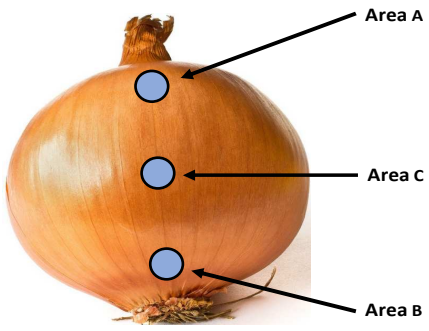

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Fig. 4. Pressure punch loads in onion areas
Rys. 4. Obszary cebuli poddane obciążeniom przy użyciu stempla dociskowego

At the beginning of the measurement, the position of the onion on the support sleeve relative to the pressure punch (figure 5) was determined. For each test, the face of pressure punch was about 1 mm from the surface of onion. The feed speed to pressure set was 100 mm · min-1, while the displacement was 15 mm. In order to determine the destructive force, the onion was loaded with force increasing over time until vegetables breakage was observed. The obtained values of forces taking into account the contact area of tool with onion were used to identify the stresses on which the onion is destroyed.

Source: [2] / Źródło: [2]

Fig. 5. Onion positioned on sleeve support and pressure punch
Rys. 5. Cebula pozycjonowana na tulei podporowej względem stempla dociskowego

The force changes at point of contact of destroyed onion and stamp are recorded, until the force value suddenly drops, which means that the breaking outer structure of the onion is forming. The resulting maximum force was used to determine the stresses on which the onion is destroyed. The cross-sectional area of the pressure punch was A≈91 mm^2. The ultimate stresses were calculated according to the following relationships:

$$\sigma = \frac{F}{A}[MPa],$$

where:
F - strength at which the onion is destroyed [N],
A - cross section area of the pressure punch used in the test [mm^2].

3. Study results and discussion

Figure 6 shows average cutting force values for individual cutting planes A, B, C with a Student-Fisher standard deviation of confidence level α = 0.90 for 20 measurements in each area.

Based on the results, it has been shown that the cutting forces are similar for three different onions. There was no characteristic tendency of force changes from point of incision on top layer. In addition, the value of cutting force is independent of the onion size. The discrepancy between the values of cutting forces depends on morphological onion characteristics.

Figure 7 shows sample runs from the cutting force measurement as a function of cutting unit displacement for a selected onion with a Student-Fisher standard deviation of α = 0.90 for 20 measurements in each area.

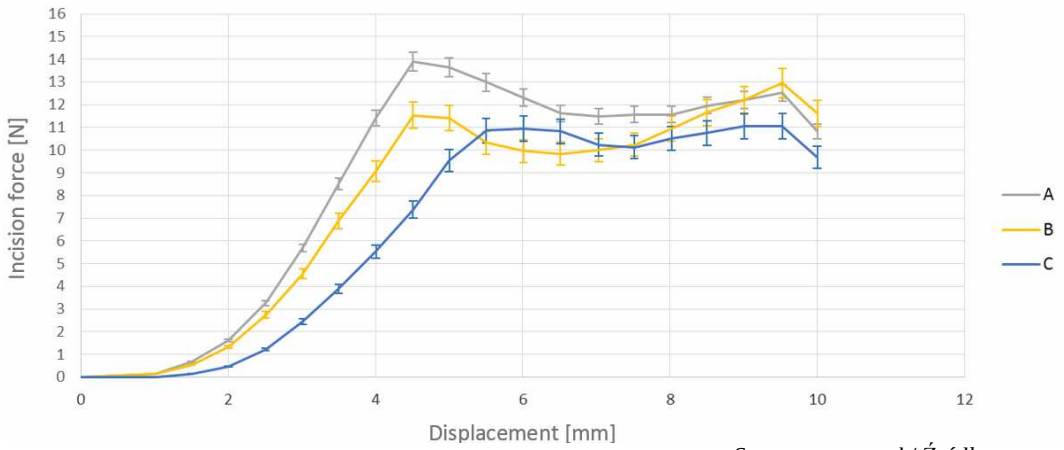

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Fig. 6. Mean values of onion incision forces
Rys. 6. Wartości średnie sił nacinania cebuli

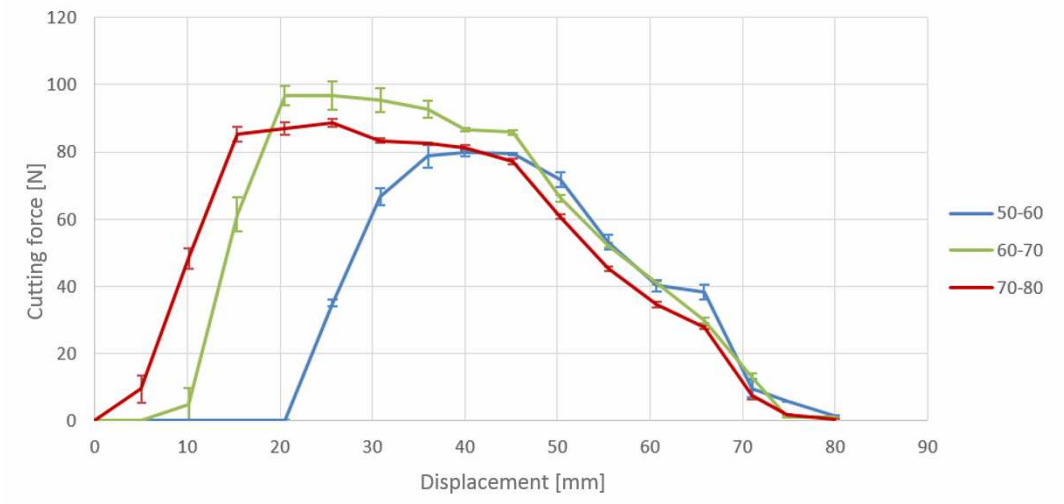

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Fig. 7. Arithmetic mean values of onion cutting forces, depending on its size
Rys. 7. Wartości średnie arytmetyczne sił przecinania cebuli w zależności od jej wielkości

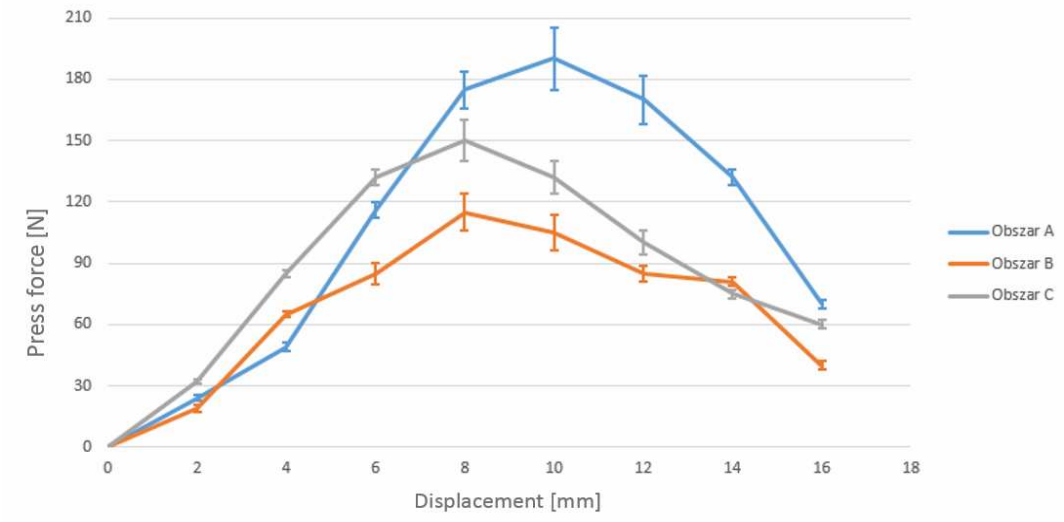

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Fig. 8. Arithmetic mean value of press force in onion areas: Area A - pinch; Area B - root; Area C - central part
Rys. 8. Wartość średniej arytmetycznej siły dociskowej w obszarach cebuli: obszar A - szczypior; obszar B - korzeń; obszar C - część centralna

As a result of study, it was observed that the shear forces obtained for bulbs from each size group differ by about 15% relative to second and third onion size compartments and by 20% relative to the first. The study allowed us to estimate the amount of force required to cut the onion, and it was noted that its maximum value was 103 N.

Figure 8 presents average pressure values for exerted pressure in the chives, root and center part of onions with a Student-Fisher error at confidence level $\alpha = 0.90$ for 10 measurements made in each of the areas.

Based on the results of study, it was confirmed that the sudden decrease in the strength value shows the onset of cracking of top layer onion, leading to its damage. For each trial in all tested areas of the onion, the maximum pressure values at which the structure is destroyed are read out. The maximum pressure values recorded during the tests are:
• in area A - of the pinch: 208 N,
• in area B - root: 124 N,
• in area C - central part: 163 N (table 1).

Table 1. Ultimate stresses according to press force value
Tab. 1. Naprężenia niszczące w zależności od wartości siły dociskowej

Load area	Pressure force [N]	Ulitmate stress [MPa]
A	208	2,9
B	124	1,7
C	163	2,3

Source: own work/ Źródło: opracowanie własne

Knowledge of the maximum stress values that destroy onion enables designers to properly engineer the actuators in the press assemblies head so that they do not produce forces causing onerous stresses greater than these damaging stresses. However, it is still necessary to adopt a safety factor. Studies have been carried out taking into account the safety factor of 0,7 values of destructive stresses and it has been observed that no onion has been damaged and that the pressing force was sufficient to stabilize it in the required position.

4. Summary

The study was designed to estimate the mechanical parameters of onions that directly affect the development of the executive members in the onion peeling unit. It has been shown that the force needed to cut top layer onion is less than 20 N, in addition, the maximum cutting force onion is 120 N, while the ultimate stresses oscillate within 1.5 to 3 MPa.

5. References

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