

Analysis of the selected mechanical properties of the root parsley

Gorzelan Józef, Matłok Natalia, Kuźniar Piotr, Zaguła Grzegorz

Department of Engineering in Agricultural Food Production, University of Rzeszów
ul. Zelwerowicza 4, 35-601 Rzeszów, gorzelan@univ.rzeszow.pl

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Summary. Such biological materials as vegetables and fruits are subject to different static and dynamic loads connected with harvesting, loading/unloading, sorting and storage. These processes lead to mechanical damage of vegetables. On the basis of the performed laboratory investigations the measurements have been made of chemical and mechanical properties of the selected varieties of root parsley.

The objective of investigations was to determine the resistance of peel and tissue of the selected varieties of parsley roots against mechanical damage occurring in the process of root penetration by means of a punch and uniaxial tissue compression (free cylindrical sample). Basic elasticity parameters of the parsley roots have been determined in form of destruction stress and apparent Young's modulus. The chemical composition of the investigated parsley varieties has also been determined.

Key words: root parsley, destruction stress, Young's modulus, chemical composition.

the influence of loads [21, 23, 24, 25]. Further, they depend on the soil environment, cultivation technology, as well as on duration and conditions of storage and the part of root selected for sampling [7, 8, 9, 14, 22, 26]. The multi-layered structure of roots of many vegetables creates additional difficulty in mechanical property investigations [1, 4, 5, 28, 29].

Investigation of mechanical properties of vegetables are frequently considered as the addition to biochemical investigations dedicated to quality of particular varieties and their storage durability [26]. Many researchers have carried out investigations connected with rheological characteristics of agricultural products. Investigation objects have comprised such crops as beets [3], potatoes [12, 20], cereal grains [18, 19] and popular vegetables and fruits, like carrots [10, 11, 13], apples [17] soybeans and tomatoes [26].

INTRODUCTION

Parsley is an edible and ornamental plant and two forms of parsley are cultivated: the root parsley and the leaf one [27]. The parsley, due to its chemical composition, belongs to the vegetable group with high nutritional and health promoting value. 100g of parsley roots contains 4.6 g of sugars, 39 mg of vitamin CD, as well as significant quantities of minerals, especially calcium, phosphorus, magnesium and iron. At the same time the ether oils contained in all plant parts give the parsley its specific flavour [5].

Plant tissues of vegetables and fruits are subject to different static and dynamic loads connected with harvesting, loading/unloading, transportation, sorting and other manipulations necessary in the process of preparation of the final product [16]. Mechanical properties of plant tissues vary not only within species but also within varieties. They depend first of all on the external load [2, 25, 30] and specific properties of tissues, like e.g. the turgor pressure, which varies under

METHODS AND MEASURING EQUIPMENT

INVESTIGATIONS OF CHEMICAL COMPOSITION OF PARSLEY ROOTS

Calorimetric investigations have been carried out with use of LECO® AC500 calorimeter (Fig. 1). Determination of water and ash contents in the root tissues of the selected parsley varieties has been performed with the use of thermal gravimetric method and LECO® AC500 instrument (Fig. 2). Instead, the analysis of carbon (C), hydrogen (H) and nitrogen (N) contents has been performed with CHN module of True Spec instrument, and sulphur (S) content with the sulphur module.

INVESTIGATION OF MECHANICAL PROPERTIES

Measurements of resistance against mechanical damage have been performed on the strength testing machine *Zwick/Roell* 2010 (fig. 3.).



Fig. 1. LECO® AC500 calorimeter.



Fig. 2. Stand for thermal gravimetric measurements.

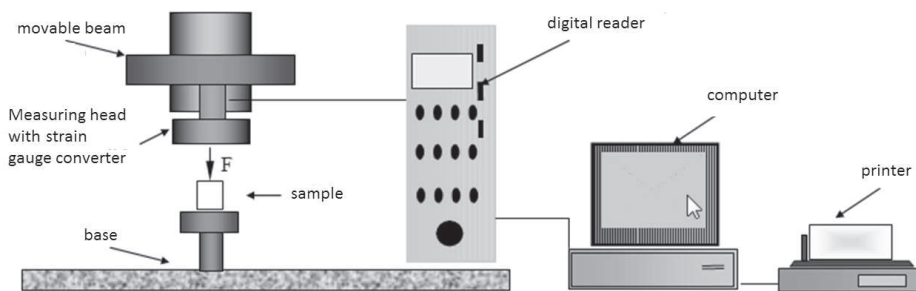


Fig. 3. Scheme of measurement stand – Zwick/Roell strength testing machine.

The investigations have been carried out for the following stationary parameter values:

- $F_v = 2\text{N}$ (preliminary load applied to sample);
- $V_1 = 40\text{mm/min}$ (speed of the settling movement of the beam/sensor assembly);
- $V_2 = 20\text{mm/min}$ (speed of the beam/sensor assembly during measurement).

The investigations have been carried out with fresh material directly after harvest. Cylindrical samples 10 mm in diameter and 20 mm in height have been cut out from two parts of the parsley roots (the top part and the central one), along the longitudinal root axis and in the transversal direction. Each series of samples comprised 15 samples from each root part and for both directions of sample cutting.

After each series of measurements the results were printed together with calculations of average values of: maximum destruction forces, strains directly before the moment of sample penetration or destruction, energies and at the same time calculations were performed for such parameters as the destruction stresses and Young's modulus.

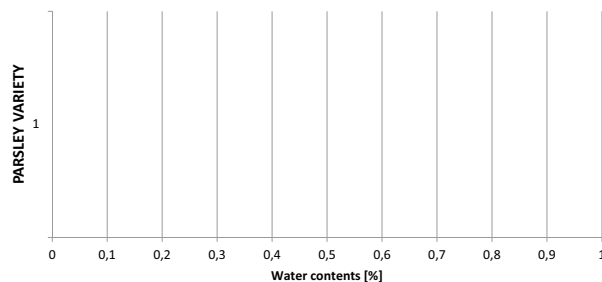


Fig. 4. Average water contents in roots of the investigated parsley varieties OŁOMUŃCKA

INVESTIGATION RESULTS

CHEMICAL COMPOSITION OF PARSLEY ROOTS

The average water content for the investigated parsley varieties was equal to 75.22%. The highest water content, equal to 79%, was stated in roots of Wistula variety, while the lowest value of 67.94% has been noted in Ołomuńska variety. The average water contents in tissues of the investigated parsley varieties, expressed in percentages, are shown in Figure 4.

The ash contents in the investigated parsley varieties were from 1.03 % for Ołomuńska variety to 1.51 % for Warta variety, while 1.33 % was the average ash content for all the investigated parsley varieties. The average percentage values of ash contents for the investigated parsley varieties are presented in Fig. 5.

It was stated on the basis of the performed investigations of chemical compositions at the angle of carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) contents in parsley roots that the highest share in chemical composition

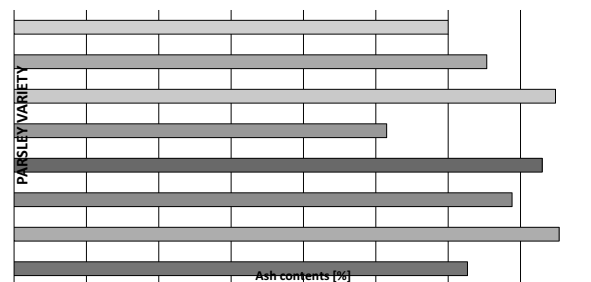


Fig. 5. Average ash contents in roots of the investigated parsley varieties OŁOMUŃCKA

tion is for carbon. The average content of this element in roots of the investigated parsley varieties is 43.79 %. The hydrogen content in parsley roots is significantly lower than for carbon and amounts to 6.42 % in average for all varieties. The nitrogen content in chemical composition of parsley roots is, on average, 1.16 %. The lowest content for this element was stated in Halblange variety, in which the nitrogen constituted only 0.37 %, while the highest content for this element, equal to 1.75 %, was observed in Sonata variety. The average calorific value for all investigated parsley varieties amounted to 3855.7 kcal/g (Table 1).

Table 1. Average contents of C, H, N and S elements and calorific values in the investigated varieties of root parsley

Parsley Variety	Contents of chemical elements [%]				Calorific values [kcal/g]
	C	H	N	S	
Roksana	44,52	6,42	1,34	0,21	3856,1
Cukrowa	42,96	6,33	1,42	0,26	3845,5
Halblange	43,69	6,53	0,37	0,08	3879,7
Ołomuńska	43,25	6,55	1,07	0,15	3763,3
Sonata	43,44	6,33	1,75	0,32	3860,7
Lenka	43,65	6,27	0,93	0,17	3878,1
Warta	44,42	6,43	1,02	0,14	3900,2
Wistula	44,38	6,49	1,38	0,13	3861,9
x	43,79	6,42	1,16	0,18	3855,7

MECHANICAL PROPERTIES

PROCESS OF UNI-AXIAL COMPRESSION (FREE SAMPLES)

Table 2 presents the average values of destruction force F_{max} [N], strain directly before the moment of sample destruction L_{max} [mm], work W to F_{max} [Nmm] to the moment of destruction, as well as the destruction stress δ [MPa] and Young modulus E_u [MPa]. On the basis of the obtained results the differentiation was stated in the measured and calculated values of parameters of the investigated root parsley varieties. The highest resistance against mechanical damage was observed in Lenka variety with destruction force of 674.7 N, while the lowest value of 483.7 N was for Cukrowa variety. The lowest average amount of energy needed for destruction of parsley tissue was stated for Roksana variety – 1485.7 nmm, while the highest amount of 2044 nmm was observed

Table 2. Average values of mechanical parameters of the investigated varieties of root parsley

Parsley variety	F_{max} [N]	dL for F_{max} [mm]	W to F_{max} [Nmm]	δ [MPa]	ϵ	E_u [MPa]
Cukrowa	483,7	6,6	1449,1	1,5	0,33	5,2
Halblange	608,0	7,6	1887,2	1,9	0,38	5,6
Lenka	674,7	6,5	1962,5	2,2	0,33	6,5
Ołomuńska	605,8	7,3	2044,0	1,9	0,37	5,9
Roksana	500,6	6,6	1485,7	1,6	0,33	5,0
Sonata	542,3	6,9	1610,8	1,7	0,33	5,5
Warta	565,2	6,9	1796,6	1,8	0,35	5,6
Wistula	591,6	6,8	1758,9	1,9	0,34	5,9

in Ołomuńska variety. The average strains directly before the moment of sample destruction were stated from 7.3 mm for Lenka variety to 8.1 mm for Ołomuńska variety. The highest elasticity was noted in Lenka variety with $E_u = 6,5$ MPa, and the lowest one – in Roksana variety ($E_u = 5,1$ MPa).

PARSLEY ROOT RESISTANCE AGAINST PENETRATION

Average values of F_{max} [N] penetration force for root peel and tissue, strain directly before the moment of sample destruction L_{max} [mm], work W to F_{max} [Nmm] to the moment of destruction and the destruction stress δ [MPa] are presented in Table 3.

On the basis of the obtained investigation results and calculations the differentiated values of the analyzed parameters were stated. The highest resistance against penetration of root peel and tissue was noted in Cukrowa variety (77.5 N), while the lowest one for Lenka (67.7 N). The average strain directly before penetration was in the range 4.5-5.5 mm. The average values of penetration energy amounted to 187.9-220.59 Nmm. The average destruction stresses for root peel and tissue were noted from 4.07 MPa (Lenka variety) to 5.40 MPa (Cukrowa variety).

Table 3. Average values of the investigated parameters in the process of penetration of peel and tissue of the root parsley with the punch 5 mm in diameter

Parsley variety	Part of root selected for sampling					
	Top part of the root			Central part of the root		
	Parameters					
	F_{max} [N]	L_{max} [mm]	δ [MPa]	F_{max} [N]	L_{max} [mm]	δ [MPa]
CUKROWA	71,74	4,76	5,29	83,28	4,40	5,52
HALBLANGE	69,19	5,36	4,82	76,71	4,61	5,38
LENKA	65,51	5,19	4,36	69,96	5,69	3,78
OŁOMUŃCKA	68,39	5,37	4,60	79,20	4,95	4,91
ROKSANA	67,60	5,28	4,63	81,70	5,52	4,23
SONATA	64,18	5,37	4,45	71,82	5,33	4,22
WARTA	69,53	5,45	4,72	75,05	5,55	4,12
WISTULA	64,10	5,47	4,22	72,55	5,15	4,30

CONCLUSIONS

- The following factors have the influence on the resistance of parsley roots against mechanical damage:
 - part of root selected for sampling and load applying direction,
 - parsley variety.
- The water contents in fresh parsley roots were differentiated. The highest water content was noted for Wistula variety (79 %), while the lowest – for Ołomuńska variety (68 %).
- The average values of penetration force of peel and tissue of parsley roots with a punch 5 mm in diameter were within the range from 67.7 N for Lenka variety to 77.56 N for Cukrowa variety. The lowest values of penetration force for peel and tissue were noted for top parts of the root.

- The average values of destruction stress for tissues of the analysed varieties of parsley roots were differentiated and were from 1.5 to 2.2 MPa.
- The average values of Young's modulus were in the range from 5.0 MPa (for Roksana variety) to 6.45 MPa (Lenka), and the relative strains were in the range 0.33-0.38.

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ANALIZA

WYBRANYCH WŁAŚCIWOŚCI MECHANICZNYCH PIETRUSZKI KORZENIOWEJ

Streszczenie. Celem badań było określenie odporności skórki i tkanki wybranych odmian korzeni pietruszki na uszkodzenia mechaniczne powstałe w procesie przebiccia stemplem oraz jednoosiowego ściskania tkanki (walcowa próbka wolna). Wyznaczone zostały podstawowe parametry sprężystości korzeni pietruszki w postaci naprężenia niszczącego oraz umownego modułu Younga. Określono także skład chemiczny badanych odmian pietruszki korzeniowej.

Słowa kluczowe: pietruszka korzeniowa, naprężenie niszczące, moduł Younga, skład chemiczny.