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INFLUENCE OF STUDY METHOD ON DESCRIPTION OF PEAR TEXTURE PROPERTIES

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Key words: pear, textural properties, storage

The aim of study was to evaluate the influence of testing method on a range of pear texture properties changes as well as to find the variability range for mechanical properties during cool storage of selected pear varieties fruits. Fruits of four pear varieties were tested. Fruit texture properties tests were performed by means of skin puncture, flesh penetrometric and flesh double compress (TPA) tests. Penetrometers with cylinder tips of 4-11 mm diameter were applied for fruit skin puncture test. Two cylinder penetrometers of 8 and 11 mm diameters ended with plano-conical, bowl-shaped and semi-sphere tips were used for flesh mechanical properties tests. Statistically significant changes of all analysed mechanical properties occurred during long-term pear storage, namely at the beginning of the process. The range of changes varies for particular quantities depending on variety traits of tested fruits. The decrease of all parameters values (except for deformation at skin puncture test) was observed during fruit storage and the course of changes was described by means of exponential equations. The tests allowed for evaluating different methods as well as finding mechanical parameters of pear texture at various storage stages. It was proved that pear texture properties depended on their variety traits. On the basis of the study it can be concluded that only application of several strength tests makes it possible to get information on pear fruit state during storage. It was found that proper selection of testing method is necessary to find differences between varieties.

INTRODUCTION

Appearance, tastiness and texture are the main determinants of product's quality accepted by consumers. For producers, texture is often a measure of material's processing quality. In Poland, many-year high production of seed fruits reaches about 2.5 million tons. Pears are several per cents in that group. They are characterised by relatively great susceptibility to mechanical injuries. Moreover, apparent change of their texture properties occurs during short-term storage [Dobrzański & Rybczyński, 2001]. Despite many years of orchard tradition in Poland, only few producers offer high-quality pears. Their firmness is one of the basic criteria of fruit texture estimation and some countries require that parameter when supplied to supermarkets [Hoehn *et al*., 2003]. Studies reveal that the fruit production chain, including harvest, storage and distribution, is in many cases imperfect. In the summer period, about 90% of fresh apples are stored under improper conditions [LeBlanc *et al*., 1996].

Attempts to define food texture along with intensive studies upon that trait have begun at the end of the XXth century [Bourne, 1968; Szczesniak, 1963]. According to the latest published works, texture is a sensory and functional indicator of structural, mechanical and surface properties of a food product that human sight, audition, touch and deep feel (kinesthesia) may receive [Surmacka-Szczesniak, 2002]. Studies upon texture properties of fruits are conducted by means of sensoric and instrumental techniques. Scientists indicate the presence of relatively high correlation between results achieved in sensory and instrumental studies, namely those of imitation character (*e.g*. TPA test). According to Polish studies, the correlation coefficient between general sensory evaluation and flesh firmness depends on fruit variety amounting for pears over 0.9 [Konopacka *et al*., 1997].

Penetrometer, puncture and compression tests (Tables 1 and 2) are most often applied for testing the texture properties of fruits.

Regardless the recommendations indicating the necessity to apply standard penetrometers (Magness-Taylor's), many researchers use rods of various sizes and shapes. Such an attempt makes the comparison of results achieved by different authors difficult. On the other hand, it is plausible, because proving the differences between tested samples is not always possible using standard testing conditions [Jackmann, 1990]. Moreover, tensile, cut, bend, torsion and twist tests are also used. A special attention should be paid to flesh tensile test that does not depend on the sample loading rate and enables precise recording the texture traits changes during fruits storage.

Fruit's susceptibility to long-term storage is determined by many factors, including climatic (temperature, rainfalls), tree properties, fertilization manner, tillage system, agrotechnical operations, or harvest term. Conditions such as temperature and relative air humidity along with atmosphere composition are the most important during fresh fruits storage.

From a pear storage point of view, mechanical injuries such as pulling out of a stalk, skin cross-outs, bruising and abrasion are important [Brusewitz & Bartsch 1989]. Many

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TABLE 1. List of parameters characterizing penetrometer and puncture tests applied for fruit and vegetable evaluation.

Author	Penetrator shape	Dimension	Loading rate	Tested object
Hoehn *et al.* [2003]	n/a	ø11.1 mm	400 mm/min	apples of Gala, Golden Delicious, Elstar cv.
Leverentz *et al.* [2003]	-	ø11.1 mm	n/a	apples of Golden Delicious cv.
Harker *et al.* [2002]	n/a	ø11 mm	240 mm/min	apples of Cox's Orage Pippin, Pacific Rose™, Granny Smith, Royal Gala, Red Delicious, Braeburn cv.
Johnston *et al.* [2002]	n/a	ø11.1 mm	n/a	apples of Granny Smith, Pacific Rose™ cv.
Chen *et al.* [2002]	semi-spherical	ø5 mm	5 mm/min	bananas of Musa cv.
Rybczyński & Dobrzański [2002]	cylindrical flat	ø6 mm	n/a	twelve apple varieties
Ortiz *et al.* [2001]	n/a	ø8 mm	20 mm/min	peaches of Maycrest cv.
DeLong *et al.* [2000]	various	n/a	n/a	various apple varieties
Harker *et al.* [2000]	rounded	ø13.16 mm ø13.16 mm	n/a 240 mm/min	strawberries of Pajaro cv.
Karlsen *et al.* [1999]	convex	ø13 mm	4 mm/s	thirteen apple varieties
Opara *et al.* [1997]	rounded	ø7.9 mm	-	apples of Gala cv.

n/a – data not available

TABLE 2. List of parameters characterizing compression and double compression tests applied for fruit and vegetable evaluation.

Author	Sample shape and dimensions	Loading rate	Tested object
Mavroudis *et al.* [2004]	cylindrical, ø15.79 mm, h= 5.98 mm	50 mm/min	apples of Kim, Mutsu and Jonagold cv.
De Smedt *et al.* [2002]	cylindrical, ø 17 mm, h=17 mm	20 mm/min	apples of Boskoop, Cox's Orage Pippin, Jonagold cv.
Herold *et al.* [2001]	Whole fruit	30 mm/min	apples of Jonica cv.
Rybczyński & Dobrzański [2002]	cylindrical, ø 13 mm, h=13 mm	n/a	twelve apple varieties
Ortiz *et al.* [2001]	cylindrical, ø 14 mm, h=14 mm	20 mm/min	peaches of Maycrest cv.
McGlone *et al.* [1997]	whole fruit	20 mm/min	kiwis
Nadulski [1996]	cylindrical ø 10 mm, h=10 mm	10 mm/min	apples of Cortland, Idared, Spartan cv.
Nishizu *et al.* [1995]	cylindrical ø 13 mm, h=30 mm	n/a	Radish
Dobrzanski *et al.* [1995]	cylindrical, ø 13 mm, h=13 mm	5 mm/min	apples of Gloster, Idared, Jonagold, Red Boskop cv.
Abbott [1983]	cylindrical, ø 15x10		seven apple cultivars
Diehl *et al.* [1979]	cylindrical ø 19.4 mm, ø 15.5 mm, h=14.6; 25.4 mm	200 mm/min	potatoes, water melons, apples

n/a – data not available

consumption pear varieties are characterised by particularly sensitive skin that is sensitive to abrasion and cross-outs. There are many publications on fruit quality issues and their mechanical injuries during harvest, transport and storage [Opara *et al*., 1997; LeBlanc *et al*., 1996; Brusewitz & Bartsch, 1989]. However, there are few works associated with complex evaluation of pear texture traits, namely in a fruit-consumer relation context. There is a small number of researches on pear texture determination by means of TPA method as well.

Variability of texture properties of seed fruits is associated with viscoelastic properties. Jakubczyk & Lewicki [2003] described the apple flesh tissue using a five-element rheological model including two Maxwell's elements combined in parallel with a spring. According to Wang [2003], pear flesh tissue was presented in a form of three-element Maxwell's model.

The aim of the present paper was to evaluate the influence of testing method on the extent of pear texture changes and to define the variability ranges for mechanical properties during cooling storage of selected pear varieties.

MATERIALS AND METHODS

Studies included four pear varieties: Bera, Konferencja, Generał and Lukasówka harvested in 2004-2005. Part of tests was performed directly after the harvest, another every 15 or 30 days. After the storage, fruits were remained in a laboratory till achieving balance with ambient conditions. Determinations of pear fruit texture properties were made by means of skin puncture, penetrometer and double compression tests (TPA).

Size and shape of fruits were determined using the vision system SUPERVIST. Fruits were placed on a measurement table with their axis directed perpendicularly and in parallel to the basis and then photos were taken. After computer processing, the pictures served for determination of minimum

TABLE 3. Physical properties of pears.

Cultivar	Minimum diameter		Maximum diameter		Equivalent diameter		Height		Weight	
	Mean (mm)	cv. (%)	Mean (mm)	cv. (%)	Mean (mm)	cv. (%)	Mean (mm)	Rel. (%)	Mean (mm)	cv. (%)
Bera	63.2	2.9	66.1	3.4	63.9	3.7	82.9	3.8	172.9	4.4
Generał	60.1	3.1	62.2	3.8	61.8	3.9	80.9	4.4	169.6	5.5
Konferencja	61.7	2.5	64.7	3.2	63.1	3.3	102.1	3.9	175.3	2.7
Lukasówka	67.2	3.0	69.6	3.4	68.9	3.5	85.1	4.1	192.3	6.4

cv. – coefficient of variability

and maximum fruit diameter, equivalent diameter and height. Fruits were weighed on electronic scales with a measurement range from 500 mg to 2100 g.

The strength tests were carried out applying an Instron 4302 device equipped in load cell of 1 kN and 10 kN capacity. Penetrometers with flat face of 4-11 mm diameter were used for fruit skin puncture test, and flesh mechanical properties were determined using two cylindrical penetrometers of 8 mm and 11 mm diameters ended with plano-conical (P), bowl-shaped (C) and semi-spherical (K) tip. Compression and double compression tests were performed using 15 mm diameter and 10 mm height cylindrical samples. Fruits were cut onto slices perpendicularly to their axis and then cylindrical samples were cut off from the flesh. On the basis of data achieved from Instron device, value of F_p force necessary to skin puncture (puncture test) with corresponding deformation L_p; value of F_m force corresponded to the penetrometer shift to 8 mm depth, rigidity coefficient SL_m and deformation work P_m (penetrometer test) as well as values of F_I and F_{II} forces at 75% of flesh sample deformation at the first and second compression cycles (double compression test).

Software of Instron series IX was used for tests, measurement data conversion was carried out using Excel worksheet, and statistical data processing was made by means of Statistica 6 software.

RESULTS AND DISCUSSION

Results of physical properties of harvested pears are presented in Table 3. Slight changes of size and weight associated with drying occurred during the storage.

The statistical analysis revealed a significant influence of penetrometer diameter and shape of end face on measurement results at penetrometer test. The lowest F_m values were achieved for penetrometers equipped in semi-spherical bowl-shaped surface (Figure 1). The statistical analysis indicated the absence of significant differences between F_{mc} and F_{mp} forces for all tested pear cultivars regardless the diameter of penetrometer applied. It points out to the possibility for applying penetrometers both with flat and bowl-shaped tip to determine pear flesh firmness.

The highest values of rigidity coefficients were recorded for 11-mm diameter penetrometers with flat end face. In the case of 8-mm penetrometers, no statistically significant differences were found between rigidity coefficients achieved by penetrometers with flat and spherical end face. However, significant differences were observed between rigidity coefficient achieved using 11-mm penetrometers for all analysed samples (Figure 2).

The lowest values of deformation work were achieved for penetrometers equipped in semi-spherical end face both for 8 mm and 11 mm (Figure 3). Regardless the penetrometer's diameter, no statistically significant differences were recorded between deformation work values achieved using penetrometers with plano-conical and bowl-shaped end face.

The influence of penetrometer diameter during skin puncture test on the possibility of recording the differences between measured quantities F_p and L_p depending on pear cultivar and storage time was analyzed. It was found that for freshly harvested fruits as well as those stored for

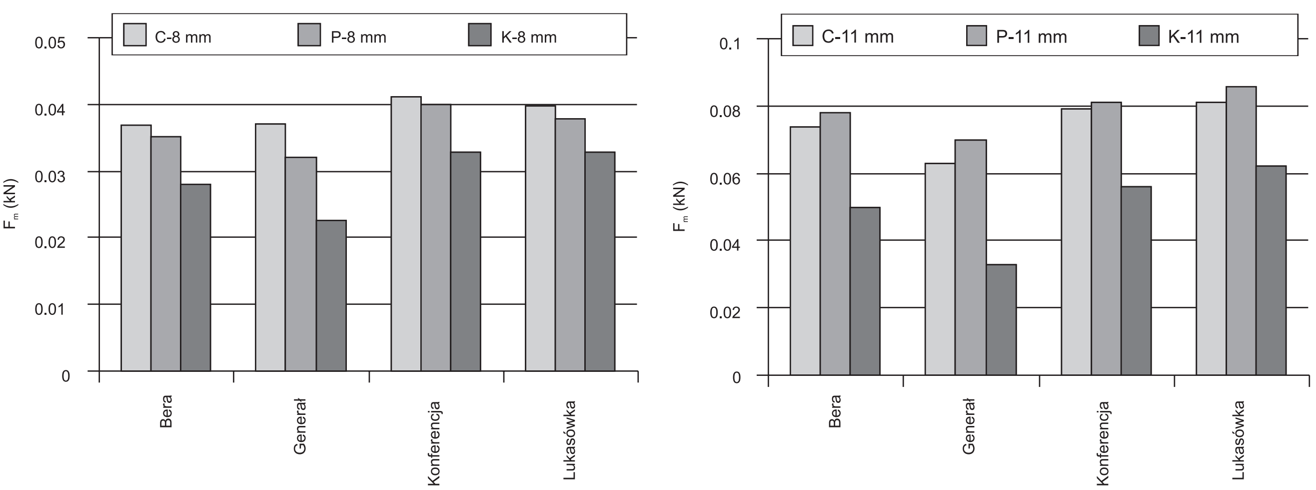

FIGURE 1. Comparison of firmness F_m for pear flesh using various-shaped penetrometers (bowl-shaped – C, plano-conical – P, semi-spherical – K) of 8 mm and 11 mm diameters.

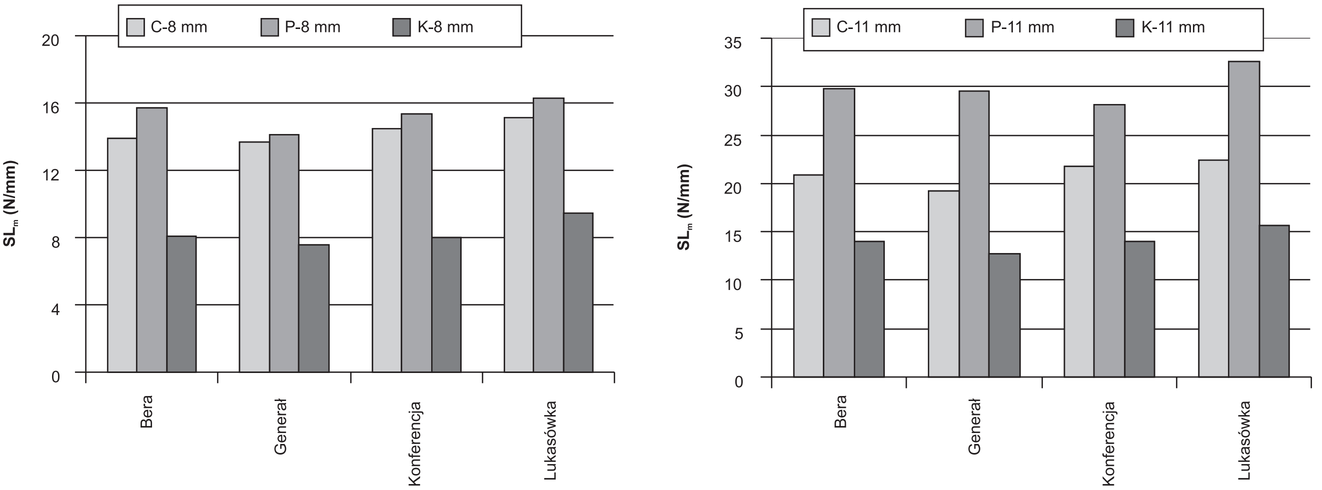

FIGURE 2. Comparison of rigidity coefficients SL_m for pear flesh using various-shaped penetrometers (bowl-shaped – C, plano-conical – P, semi-spherical – K) of 8 mm and 11 mm diameters.

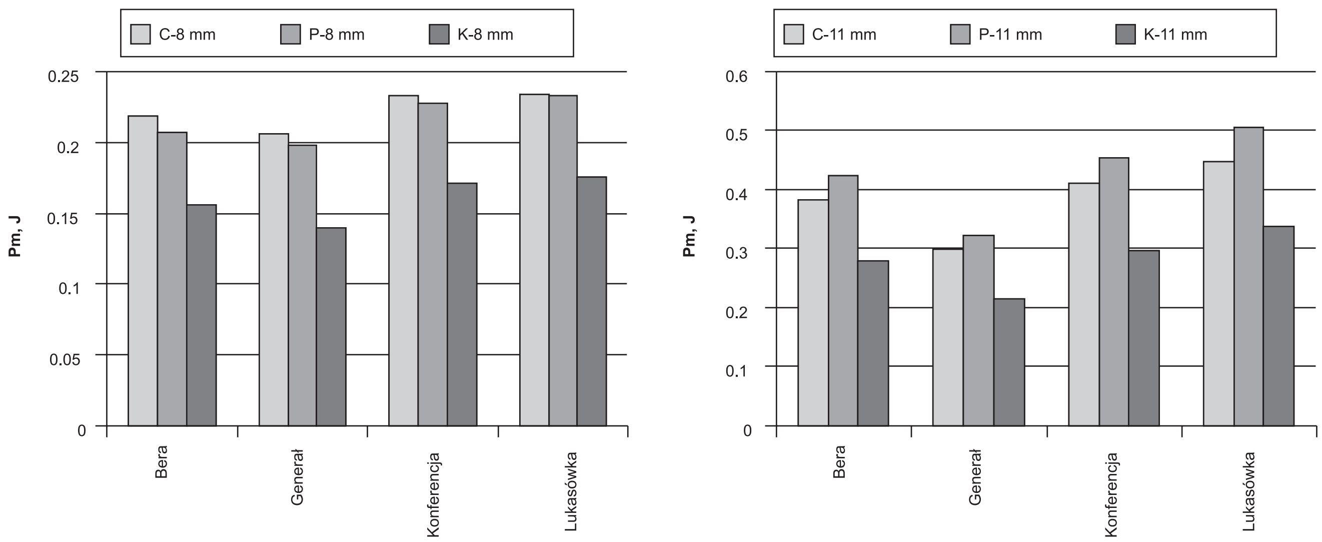

FIGURE 3. Comparison of deformation work Pm for pear flesh using various-shaped penetrome-ters (bowl-shaped – C, plano-conical – P, semi-spherical – K) of 8 mm and 11 mm diameters.

30 days, statistically significant differences occurred for F_p force values achieved using penetrometers with above 5 mm diameter. Studies revealed also that the application of penetrometers with diameters below 8 mm failed to demonstrate differences of F_p force between the tested cultivars (Figure 4). The values of deformation L_p at skin for four pear varieties and various diameter of penetrometer are presented in Figure 5.

Statistically significant changes of all analysed mechanical properties, namely at the initial stage, occurred during long-term storage of pears. The extent of changes was different for particular quantities and depended on fruit variety

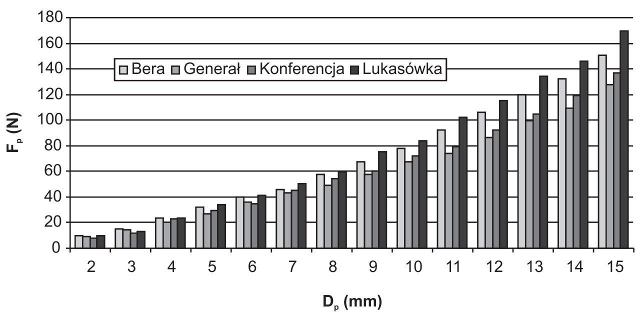

FIGURE 4. Force F_p at skin puncture for four pear varieties and various diameter of penetrometer.

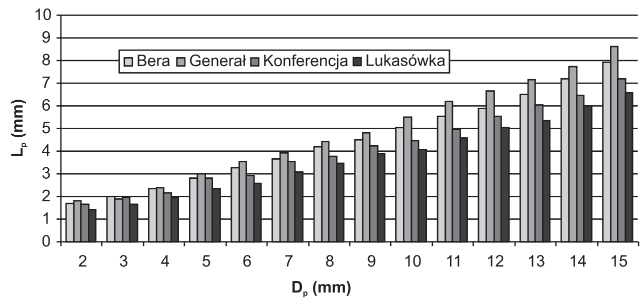

FIGURE 5. Deformation L_p at skin puncture for four pear varieties and various diameter of penetrometer.

traits. The decrease of all properties, except for deformation at skin puncture test, was observed during the storage and these changes were expressed as exponential equations. In the case of pear fruits, stony cells had the effect on their texture properties. Their presence makes non-uniformity of material greater and results in great discrepancy of results from strength properties measurements.

Changes of the analysed quantities during the storage are presented in Figures 6, 7 and 8. Among pear cultivars tested, the highest force values were achieved for Bera cv., whereas the lowest ones for Generał cv. Studies revealed that different extent of changes in the analysed traits was due to the testing method applied.

CONCLUSIONS

Studies enabled evaluating various testing methods and measuring the mechanical parameters of pear texture at different storage stages. It was found that pear texture properties differed between varieties. On the absis of determination of mechanical properties it can be supposed that application of many strength tests enabled achieving information on pear fruits state during the storage. The description of pear condition during storage using a single quantity, *i.e.* firmness, from a point of view of texture, is insufficient. It was proved that a proper selection of testing method is necessary to find the variability at each variety. The performed study is not only of cognitive, but also practical character. It may be useful for orchard farmers to predict changes of many mechanical properties of pears during their storage.

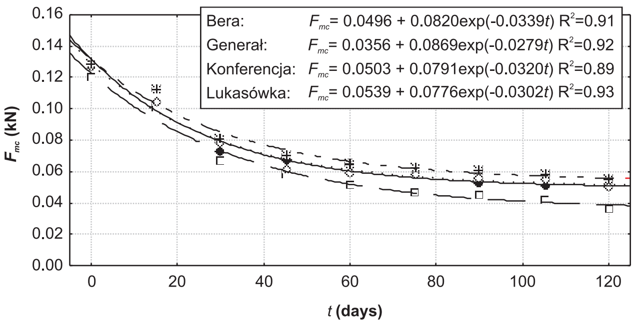

FIGURE 6. Influence of storage time on flesh firmness F_{mc} of pear.
(— BERA CV., − − Generał cv., ······ Konferencja cv., −··−Lukasówka cv.)

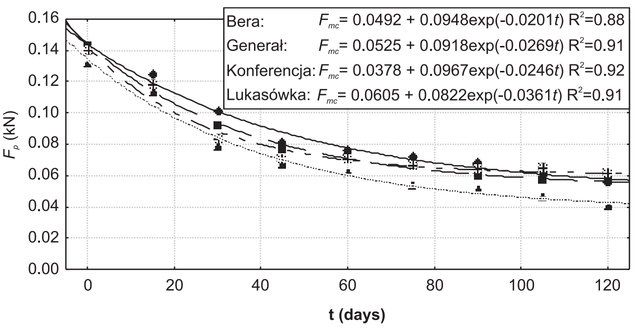

FIGURE 7. Influence of storage time on puncture force F_p of pear skin.
(— BERA CV., − − Generał cv., ······ Konferencja cv., −··−Lukasówka cv.)

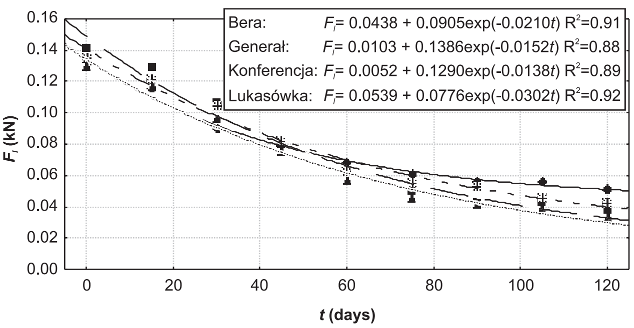

FIGURE 8. Influence of storage time on flesh hardness F_l of pear.
(— BERA CV., − − Generał cv., ······ Konferencja cv., −··−Lukasówka cv.)

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WPŁYW METODY BADAŃ NA OPIS WŁAŚCIWOŚCI TEKSTURALNYCH GRUSZEK

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Celem pracy było określenie wpływu metody pomiaru na zakres zmian właściwości teksturalnych gruszek a także wyznaczenie właściwości mechanicznych wybranych odmian gruszek podczas przechowywania w warunkach chłodniczych. Badaniami objęto cztery odmiany gruszek. Badania teksturalne prowadzono przy pomocy testu przebijania skórki, testu penetrometrycznego miąższu i testu podwójnego ściskania (TPA). Do przebijania skórki owoców stosowano penetrometry cylindryczne o średnicy od 4 mm do 11 mm. Test penetrometryczny miąższu prowadzono przy pomocy penetrometrów cylindrycznych o średnicy 8 mm i 11 mm z końcówkami: płaskościętą, półkulistą i czaszową. W czasie długotrwałego przechowywania zarejestrowano istotnie statystycznie zmiany analizowanych cech teksturalnych owoców, szczególnie w początkowej fazie przechowywania. Podczas przechowywania zaobserwowano spadek wartości wszystkich analizowanych wartości (oprócz deformacji skórki) a zmiany opisano przy pomocy funkcji wykładniczych. Badania pozwoliły na porównanie różnych metod pomiarowych oraz wyznaczenie cech teksturalnych owoców podczas przechowywania. Przeprowadzone badania wykazały, że jedynie stosowanie wielu testów wytrzymałościowych pozwala na uzyskanie informacji o stanie owoców w różnych stadiach przechowywania chłodniczego. Stwierdzono, że tylko właściwy dobór metody badawczej pozwala na określenie różnic między badanymi odmianami owoców.