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Assessment of Mechanical Properties of Fresh Fruit and Brine Pickles Obtained from Selected Varieties of Field Cucumber, Depending on the Chemical Composition of Brine, Duration of Pickling and Additional Starting Cultures

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Summary. Monitoring of the mechanical properties of fruit obtained from cucumber plants is extremely important because of their use in processing, since these properties are reflected by the finished products of processing. Mechanical defects produced at the time of harvesting, during transport and at the specific stages of processing may adversely affect the course of technological processing (brine and vinegar pickling), resulting in spoilt preserves no longer useful for commercial purposes. The study was designed to identify selected mechanical properties in fresh and pickled fruit obtained from field cucumbers during spontaneous fermentation and fermentation promoted by selected lactic bacteria cultures. Additionally, water contents were measured in fresh cucumbers. The findings show significant differences between the analysed parameters.

Key words: field cucumber, pickling, peel and flesh puncture strength, water contents.

INTRODUCTION

Cucumber (Cucumis sativus L.) is an annual, allogamous plant representing gourd family. It has high requirements related to temperatures and soil. The plant originated in India and as a result cucumber is highly sensitive to ground frost, winds and cold weather, it requires fertile and highly permeable soil, which warms up rapidly and is free of frost pockets [1, 2]. The optimum temperature for germination is approx. 30 °C, yet growing in the field, the plant can develop at slightly lower temperatures, exceeding 18°C [5, 19].

The processing of vegetables based on fermentation and preservation with vinegar and sugar, designed to improve their stability has been commonly used for centuries. Food processing industry includes a wide range of plants specializing in such produce as cucumbers and cabbage as well as dried vegetables. The highly processed products account for 25% of fruit and vegetable preserves production [13, 18].

Fermentation is a long-lasting process depending to a large degree on temperature, the quantity of multiplied lactic bacteria, the contents of sodium chloride in the brine, as well as the choice of suitable starting cultures. This is a method of preserving raw materials with high water contents and chemical composition enabling accumulation of the desirable microorganisms promoting fermentation and playing the role of natural preservatives [4, 14].

Lactic acid fermentation is an anaerobic process of transformation of sugars (glycolysis) present in the raw material into lactic acid, accompanied with enzymatic changes of proteins and lipids promoted by proteases and lipases, which produce non-toxic aromas, flavours and substances modifying the texture of the produce and result in properties which are attractive for consumers. Such vegetable products have also been found with reduced contents of anti-nutrients, such as protease and phytate inhibitors responsible for malabsorption of proteins and trace elements [6, 24].

When fermentation process is carried out by homofermentative bacteria, lactic acid is the only product of metabolism of microorganisms. If heterofermentative bacteria are involved in the process, other compounds are generated in addition to the main product; these include acetic acid, ethyl alcohol, glycerine, acetic aldehyde, butanediol [3, 8, 23]. The environment hosting the fermentation reaction is found with a decrease in pH, from 5.5 to 3.5 leading to slower pace of enzymatic changes and breathing processes in the tissues, which results in oxidation of ascorbic acid and browning of the surface [3, 8, 17, 23]. Such low pH is mainly responsible for microbiological conservation of the fermented products as very few pathogens can survive in environmental conditions of this kind [22].

Mechanical properties of cucumbers are examined in order to optimize the cultivars selection, harvesting, storage, transport and processing. Cucumbers are characterized by significant anisotropy, therefore it is necessary to conduct studies on a cyclical basis and to adopt comprehensive approach. As a result it is possible to easily identify the quality of the raw material, i.e. its firmness and hardness which are

evaluated by both manufacturers of vegetable preserves and consumers [10, 12, 20, 21]. Non-uniform values of puncture strength parameters adversely affect the analysis of mechanical properties with the use of basic puncture test [15].

Research has been carried out to identify the value of peel and flesh puncture strength in raw cucumbers and in those subjected to fermentation, and it has been shown that the puncture strength does not only depend on the size, water content in the produce and the location of puncture but also on the duration of pickling process and chemical composition of the brine [11, 16].

Puncture strength was also examined in raw cucumbers and those subjected to brine pickling process, with a punch probe, diameter of 5 mm. It was established that puncture strength decreased during the pickling process, yet a comparison of cucumbers treated with two different pickling methods showed that those processed with an addition of lactic acid bacteria were characterized by greater puncture strength [25]. Similar conclusions were reached by Fleming et al. who examined mechanical properties of cucumbers in a similar way [7].

The present study investigated the relation between the chemical composition of the brine used in the process of pickling and the properties of the final product and assessed resistance of raw and brine pickled cucumbers to mechanical damage as a result of cutting through the peel and flesh with a 5 mm punch probe, at four dates of measurements. The study also examined water contents in fresh cucumbers.

MATERIAL AND METHODS

The research material comprised three cultivars of field cucumber: Izyd F_1, Polan F_1 and Śremski F_1, and was acquired from a specially designed ecological culture. The experimental plots were located in Medynia Łańcucka (Podkarpackie Region, Poland). The relevant parameters were measured in fresh cucumbers and in cucumbers subjected to spontaneous lactic fermentation and targeted fermentation with the use of EmFarma Plus probiotic from ProBiotics Polska. The material was divided into two size fractions (1st fraction included 3.5 – 5.5 cm long fruit, and 2nd fraction consisted of fruit ranging from 6.0 to 8.0 cm in length), which were taken into account in the measurements. The material was also differentiated by the duration of pickling, and the measurements were carried out at defined stages of fermentation: on day 10, 30, 60 and 90 after the start of the pickling process.

WATER CONTENTS MEASUREMENT:

Water contents in raw fruit were examined using the dryer method. The measurements were performed with the use of laboratory incubator and moisture balance. The research material was divided into size fractions; the samples acquired from each fraction consisted of slices, a few mm in thickness. The samples were obtained from three parts of the cucumber: at the leaf stalk base, in the middle and at the top end of the fruit. Suitably marked samples were placed for 6 hours in the incubator where they were subjected to initial drying at 70ºC. Then, they were dried up in the moisture balance at the temperature of 105ºC.

Water contents in fresh fruit obtained from field cucumber were computed based on the formula:

$$W = \frac{m_1 - m_2}{m_1} * 100\%,$$

where:
W – water content [%],
m_1 – mass of fresh samples [g],
m_2 – mass of dry samples [g].

PEEL AND FLESH PUNCTURE STRENGTH MEASUREMENT:

The mechanical properties of cucumbers were measured with the use of Zwick/ Roell testing machine. The fruit were punctured by applying a punch probe with a diameter of φ=5 mm. The cucumbers were punctured at three measuring locations (at the leaf stalk base, in the middle and at the top end). Each series of measurements consisted in 12 trials. The measurements were carried out separately for the 1st and 2nd size fraction, for fresh cucumbers and during defined stages of pickling, after 10, 30, 60 and 90 days of fermentation.

Statistical analyses were carried out using Statistica 10 software. Shapiro-Wilk test was applied to examine data distribution in order to verify normal distribution and homogeneity of variances. Confidence level was assumed at α=0.05. Subsequently one-way ANOVA was performed to determine the significance of differences between the means. If the aforementioned analyses confirmed there were differences between the mean values of the parameters, post-hoc Tukey's test was applied to obtain more precise information and to verify the findings.

RESULTS

WATER CONTENTS:

Mean water contents in the selected field cucumber cultivars were in the range of 94.0-95.0%. Slightly higher contents were observed in the 2nd size fraction. As for the location of the measurement, higher water contents were identified at the base of the fruit. As an exception Izyd cultivar was found with higher water contents in the central part of the fruit.

A comparison of water contents in three cultivars of field cucumber shows the highest values in Śremski variety, at the level of 95.0%, and the lowest in Polan cultivar, amounting to 94.0 %.

ANALYSIS OF PEEL AND FLESH PUNCTURE STRENGTH IN RAW CUCUMBERS:

The force F [N] needed to cut through peel and flesh of the fruit of cucumber depends on water contents, fruit size,

Table 1. Mean water contents in raw fruit

Variety and fraction	Water contents [%]			
	Fruit leaf stalk base	Middle part of the friut	End part of the fruit	Average
Polan Frakcja I	94,2	93,8	94,1	**94,0**
Polan Frakcja II	94,9	94,0	94,7	**94,5**
Izyd Frakcja I	94,4	94,8	94,3	**94,5**
Izyd Frakcja II	94,3	95,0	94,8	**94,7**
Śremski Frakcja I	95,1	94,9	94,9	**95,0**
Śremski Frakcja II	95,3	94,3	95,2	**94,9**

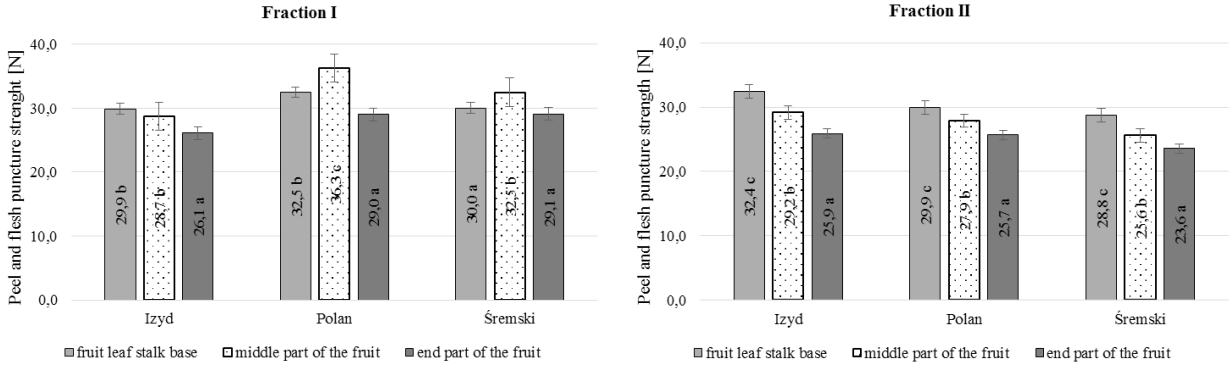

Fig. 1. Mean value of peel and flesh puncture strength in raw cucumbers, taking into account three locations of puncture. 1st and 2nd fraction

location of puncture, and variety of the produce determining its physicochemical properties.

Values of peel and flesh puncture strength in cucumbers relative to the size fraction, location of puncture and cultivar are presented in Figure 1.

In the 1st size fraction the highest mean value of puncture strength in the fruit of cucumber was observed in Polan variety, in the central part of the fruit, and it amounted to 36.3 N. The lowest value of puncture strength, at the level of 26.1 N, was found in Izyd cultivar, at the top end of the fruit.

In the 2nd size fraction the highest mean value of puncture strength, i.e. 32.4 N, was recorded for Izyd variety, and the lowest 23.6 in Śremski cultivar. As for the 2nd size fraction, the examined cultivars had the highest peel and flesh puncture strength at the base and the lowest puncture strength at the top end of the fruit.

A comparison of the two size fractions of raw cucumbers suggests that the 2nd size fraction was more resistant to mechanical damage resulting from puncture by the punch probe.

Within a single cultivar, raw Izyd cucumbers of the 1st size fraction were characterized by lower puncture strength than the fruit of the 2nd size fraction. In Polan and Śremski variety, fruit of the 1st size fraction had higher puncture strength than those of the 2nd size fraction of the same cultivars. The differences between the values of puncture strength in the 1st and 2nd fraction were most visible in Śremski cultivar, and least notable in Polan cultivar.

The analysis of the measurements of puncture strength performed at consecutive stages of fermentation in brine A, taking into account the two size fractions, showed that field cucumbers of the 2nd fraction, regardless of the cultivar, had lower puncture strength in comparison to cucumbers of the 1st fraction.

The value of puncture strength measured during the process of pickling in brine A, which promoted spontaneous fer-

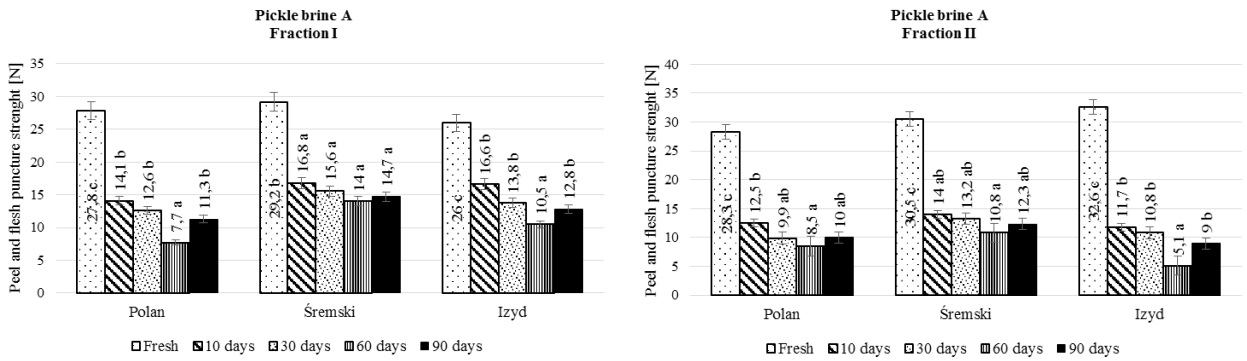

Fig. 2. Mean values of peel and flesh puncture strength in raw cucumbers and at the specific stages of pickling, relative to cucumber cultivar. Brine A.

mentation, reached the lowest level on day 60 of the pickling process. A comparison of puncture strength values in raw fruit and pickled cucumbers on day 60 of the fermentation process shows an over three-fold decrease in the puncture strength. This phenomenon confirms that during fermentation the produce becomes softer due to decomposition of sugars and diffusion of substances from a cucumber to the brine. The minimum value of the examined parameter suggests the end of the phase of logarithmic growth of the fermenting micro-organisms and the changes promoted by them in cucumber fermentation. Their transition into the inhibited growth phase and the end of the fermentation process should be reflected by the fact that at the next stage puncture strength values remain at the same level. Visible increase in the value of the parameter may result from continuous diffusion of elements between the produce and the brine.

In the group of the three examined cucumber cultivars pickled in brine A, both the 1st and the 2nd size fraction of Śremski cultivar were characterized by the highest puncture strength from day 10 of the fermentation process; the relevant value for the 1st fraction amounted to 16.8 N, and for the 2nd fraction 14.0 N. In comparison to Polan cultivar with the value of the parameter at the level of 7.7 N at the final fermentation stage, for the 1st fraction, the hardness of the product is two times lower. This proves that Śremski cucumbers are more suitable for pickling. Similarly, the 2nd size fraction of Śremski cultivar was found with higher values of puncture strength, yet there were smaller differences between the cultivars.

Like in the case of cucumber pickling with the use of brine A, analysis of targeted fermentation process suggests that Śremski cucumbers are most suitable for pickling. On the 90th day of the process, the 1st and the 2nd size fractions of Śremski cucumbers were found with the highest values of puncture strength: 14.2 N and 8.8 N, respectively. These values are similar to those identified during the process of cucumber pickling with the use of brine A. The remaining puncture strength values measured at the defined dates during the pickling process were lower than during the spontaneous fermentation in brine A only in the case of Izyd cultivar.

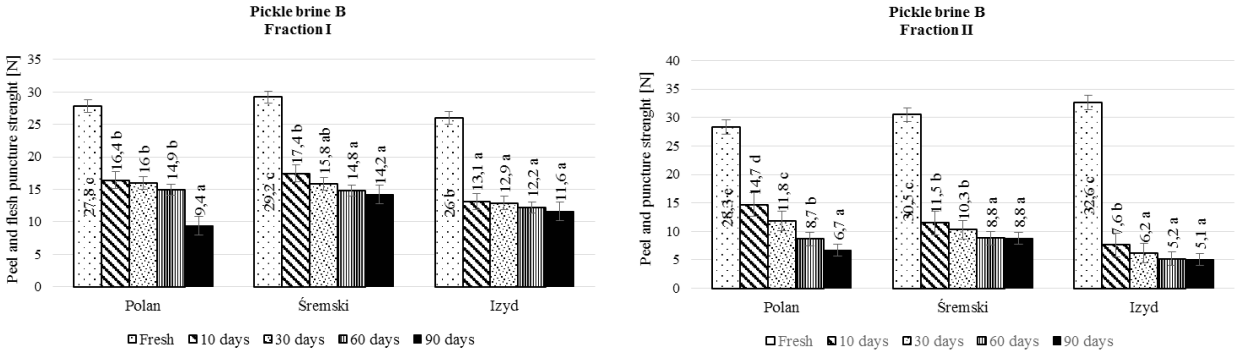

Fig. 3. Mean values of peel and flesh puncture strength in raw cucumbers and at the specific dates of measurement during the pickling process, relative to cucumber cultivar. Brine B

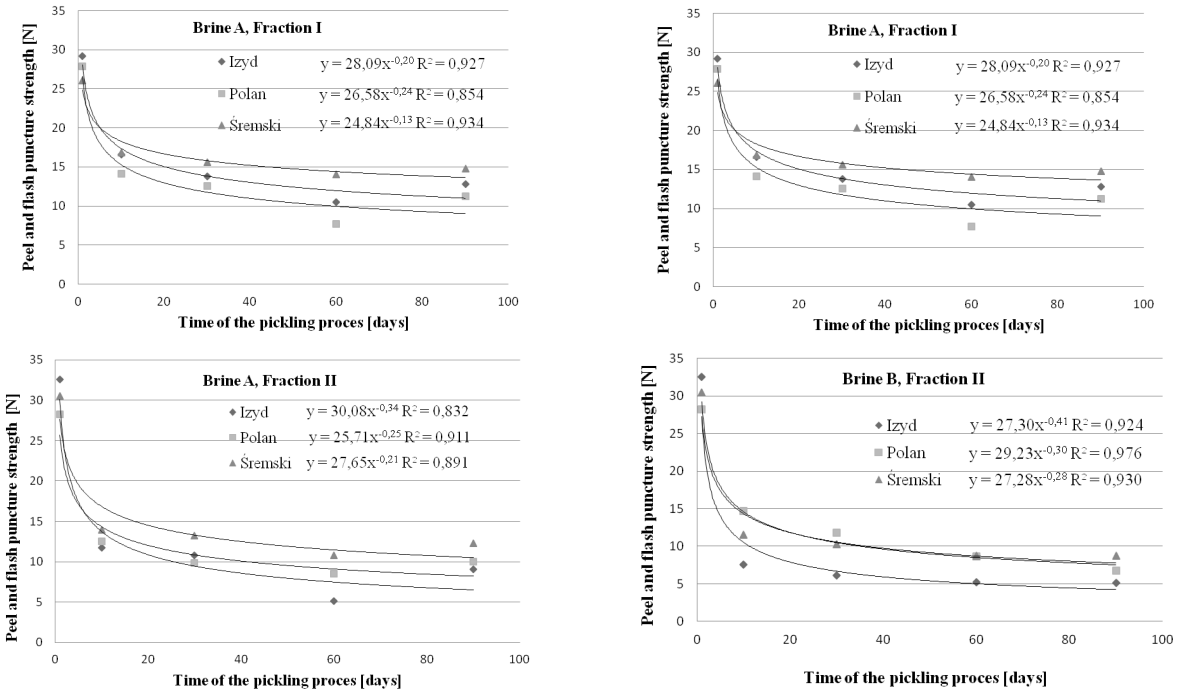

Fig. 4. Trend lines for the mean values of peel and flesh puncture strength of three cultivars, relative to the size fraction and chemical composition of the applied brine

Figure 4 presents trend lines for the relationships between the mean values of peel and flesh puncture strength in cucumbers and the time from the start of the pickling process, for two variants of chemical composition of the brine.

The analysis of the findings confirms that the value of puncture strength depends on the time from the start of the pickling process. The coefficients of determination reach higher values in cucumbers subjected to spontaneous fermentation process, both in the 1st and in the 2nd size fraction. The highest value at the level of R^2=0.84 was recorded in Izyd cultivar, the 1st fraction pickled in brine A. Similarly, the lowest value of the coefficient of determination, R^2=0.63 was recorded in Izyd cultivar, pickled in brine B. The smallest differences in the coefficient of determination for the two variants of brine can be seen in Śremski cultivar, while the greatest differences in these coefficients are identified in Izyd cultivar which was found with the two extreme values.

CONCLUSIONS

1. Mean water contents in the cucumbers of the examined cultivars were in the range of 94.0-95.0%, and the highest value was observed in Śremski Mieszaniec F1 cultivar.
2. Mean value of peel and flesh puncture strength in the fresh fruit of the examined cucumber cultivars ranged from 23.6 N to 36.3 N. The highest value of peel and flesh puncture strength was found in the central part of Polan cucumbers, the 1st size fraction, and the lowest was observed at the top end of the fruit in the 2nd fraction of Śremski cultivar. In the 2nd size fraction the highest puncture strength was found at the base of the fruit and the lowest values at the top end.
3. Mean values of puncture strength decreased at the consecutive stages of fermentation and at the final stage were 2.0-2.5 times lower in the cucumbers pickled in brine A. The use of brine B resulted in a two-fold up to six-fold reduction in puncture strength.
4. Field cucumbers of Izyd cultivar were found with the largest puncture strength related differences between fresh and pickled fruits; the value of this parameter was in the range of 32.6-5.1 N. On the other hand field cucumbers of Śremski cultivar showed the smallest differences in peel and flesh puncture strength between the raw and pickled fruits. The value of the strength ranged from 30.5 to 8.8 N.
5. The findings showed an influence of the duration of pickling and composition of brine on the value of peel and flesh puncture strength in cucumbers. The cucumbers subjected to targeted lactic fermentation were characterized by lower values of the parameter, yet these values were less varied than the values in the cucumbers pickled with the use of brine A promoting spontaneous fermentation of the produce.
6. It has been demonstrated there was a relationship between peel and flesh puncture strength and the size fraction of the fruit. Smaller cucumbers had greater puncture strength, in the range of 17.4-9.4 N, than the larger cucumbers, in which the parameter was found to range from 14.7 to 5.1 N.
7. The coefficients of determination describing the relationship between puncture strength and duration of pickling were in the range R^2=0.63-0.84 for the 1st size fraction and R^2=0.66-0.83 for the 2nd fraction. The highest value of the coefficient was observed for brine A and Izyd cultivar, and for brine B and Polan cultivar.

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OCENA WŁAŚCIWOŚCI MECHANICZNYCH WYBRANYCH ODMIAN ŚWIEŻYCH ORAZ KISZONYCH OWOCÓW OGÓRKÓW GRUNTOWYCH, W ZALEŻNOŚCI OD SKŁADU CHEMICZNEGO ZALEWY, CZASU ZAKISZANIA ORAZ DODATKU KULTUR STARTEROWYCH

Streszczenie. Monitorowanie właściwości mechanicznych owoców ogórków jest bardzo ważne, ze względu na ich przeznaczenie do przetwórstwa, bowiem mają one swoje odzwierciedlenie w gotowych produktach powstałych w wyniku przetworzenia surowca. Uszkodzenia mechaniczne powstałe w wyniku zbioru, transportu, czy na poszczególnych etapach przetworzenia mogą doprowadzić do nieprawidłowego przebiegu procesu technologicznej obróbki (kiszenia, marynowania), a tym samym zepsucia i dyskwalifikacji gotowych przetworów. Celem badań było określenie wybranych właściwości mechanicznych świeżych oraz kiszonych owoców ogórków gruntowych w czasie trwania fermentacji spontanicznej oraz z wykorzystaniem wyselekcjonowanych kultur bakterii mlekowych. Wykonano również pomiar zawartości wody w świeżych owocach ogórka. Stwierdzono występowanie istotnych różnic pomiędzy analizowanymi parametrami.

Słowa kluczowe: ogórek gruntowy, kiszenie, siła przebicia skórki i miąższu, zawartość wody.