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INFLUENCE OF PACKAGES ON NUTRITIONAL QUALITY OF PICKLED CHILLED STORED CUCUMBERS

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Abstract: Due to instability of fresh cucumbers during storage and their seasonal availability, different methods are used to preserve them, of which pickling is one of the most favourable. The aim of this paper was to investigate the effect of package type (bags made from low density polyethylene (PE-LD) and the metalized polyethylene terephthalate (PET met/PE) foil) on selected quality parameters of pickled cucumbers. Vegetables were analysed in 2014 before packaging and after 1, 2, 3, and 4 months of chilled storage in two types of a package. It has been found that the package type used had no statistically significant ($p > 0.05$) effect on dry matter content, vitamin C content, nitrate and nitrite contents and antioxidant activity of the pickled cold stored cucumbers. The level of total polyphenols was statistically significant ($p \leq 0.05$) in pickled cucumbers stored in bags made from the metalized polyethylene terephthalate (PET met/PE) foil.

Keywords: cold-stored, packaging, pickled cucumbers, nitrates, nitrites, vitamin C, antioxidant activity

Introduction

Cucumber (*Cucumis sativus* L.) which belongs to the gourd family *Cucurbitaceae*, is one of the most popular, economically important and widely grown vegetable crops in the world [1]. Cucumber fruit is a good source of mineral compounds and dietary fibre and contain approximately 95% water, 3.6% carbohydrates, and 0.65% protein and are low in calories. They are a good source of the vitamin C (8 mg/100 g), retinol equivalent (28 μg/100 g), vitamin E (0.16 mg/100 g) and B-group vitamins, including folic acid (15 μg/100 g) and pantothenic acid [2].

Pickling cucumber is grown in many parts of the world. Pickling, as one of the biological methods of food preservation, is used since ancient times. This process runs due to lactic acid fermentation and the products obtained are characterized by longer

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shelf life, are microbiologically safe, easy digestible, simultaneously showing different properties than the initial raw material [3].

The World Health Organization has listed pickled vegetables as a possible carcinogen because of nitrites content. For this reason, the measurement of nitrite content in pickled vegetables has received increasing attention [4]. In the present study, we analyzed also the content of nitrite in pickled cucumber and the results should help to choose the kind of packaging material, which will be the most suitable for the chilled storage of pickled cucumber.

The weakness of vegetables is their seasonal availability and fact that they are perishable. In view of the above, food technology is focused on discovering and establishing the methods of storage, which will least affect their chemical composition. However, such a high amount of water determines the limited stability of cucumbers, creating good conditions for the growth of micro-organisms. Pickling cucumbers are generally stored in the brine for long-term storage. To our best knowledge this is the first study determining the effect of cold storage in different packaging type (especially innovative is one of presented packaging type – metalized foil made from PET met/PE) on selected antioxidative properties and content of some contaminants in pickled cucumbers.

The aim of this paper was to examine and compare pickled cucumber, which was chilled stored for four subsequent months, in terms of changes in the dry mass, vitamin C, total polyphenols, nitrates and nitrites content as well as antioxidant activity. The experimental material was packed in two ways: in low density polyethylene (PE-LD) bags and in metalized polyethylene terephthalate (PET met/PE) bags.

Overall, this study were undertaken to broaden knowledge on health-promoting properties of pickled cucumber, particularly in terms of the following indicators: vitamin C, total polyphenols and antioxidant activity. This study aimed also at increasing the consumer knowledge about biological value of the pickled cucumber, particularly with regard to the presence of such contaminants as nitrates and nitrites.

Material and methods

Material

The experimental material consisted of freshly pickled cucumbers, purchased in selected five sites of direct sales in the city of Krakow in 2014. Vegetables were analysed before packaging and after 1-, 2-, 3- and 4-month periods of chilled storage in the two types of the package: in the low density polyethylene (PE-LD) bags with the zipper closure (foil density: 0.91–0.92 g/cm^3; size: 230 × 320 mm); and in the bags of the similar size made of the laminate: metalized polyethylene terephthalate (PET met/PE) (a polymer from the polyester group, obtained through a polycondensation reaction between dimethyl terephthalate (DMT) and ethylene glycol (GE), CAS number: 25038-59-9, density 1.370 g/cm^3) with polyethylene. The representative samples obtained were then stored at chilled conditions (4–5^{o}C) in a fridge for four subsequent months.

Analytical methods

The experimental material taken before packing and after the established periods of chilled storage from every container was collected and then homogenized using a homogenizer (CAT type X 120) in order to obtain a mean representative sample.

Adequately prepared mean representative samples of vegetables were analyzed for vitamin C content and the levels of contaminants: nitrates and nitrites. Simultaneously, 70% methanol extracts has been prepared to determine: total polyphenols (calculated per chlorogenic acid) – through the colorimetric measurement of colourful substances formed due to the reaction between phenolic compounds and a Folin-Ciocalteau reagent (Sigma) [5] and to determine antioxidant activity based on the $ABTS^+$ free radical scavenging ability – by a colorimetric assessment of an amount of the $ABTS^+$ free radical solution, which had not been reduced by the antioxidant present in the products examined [6].

The content of vitamin C was determined as the sum of ascorbic acid and dehydro-ascorbic acid using 2,6-dichlorophenoloindophenol according to PN-A-04019:1998 [7]. Oxalic acid solution was used for extraction of the ascorbic acid.

The content of total phenols in the extracts was determined spectrometrically (at a wavelength of 760 nm using a RayLeigh UV-1800 spectrophotometer) according to the Folin-Ciocalteu procedure and calculated as chlorogenic acid equivalents (CGA) (in terms of milligrams) per 100 g of fresh or dry weight, based on a standard curve.

The method involved colorimetric determination of the amount of the colored solution of $ABTS^+$ free radical (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) which was reduced by the antioxidants present in the test product. The absorbance was measured at a wavelength of 734 nm using a RayLeigh UV-1800 spectrophotometer. Values obtained for each sample were compared to the concentration-response curve of the standard trolox solution and expressed as micromoles of Trolox equivalent per gram of fresh or dry weight (TEAC).

Colorimetric method using to determinate contaminants such as nitrates and nitrites based on nitrites coloured reaction with Griess I, II reagent according to the Polish Standard [8]. Previously nitrates must be reduced to nitrites. Nitrates content was assessed using Griess I (sulfanilamide, Sigma-Aldrich) and Griess II (n-(1-Naphtyl)ethylene-diamine dihydrochloride, water solution, Sigma-Aldrich). The principle of this method is to cause a colour reaction of nitrate(III) with n-(1-Naphtyl)ethylene-diamine dihydrochloride in acidic conditions, and to measure absorbance at wavelenght 538 nm. Nitrates had tobe reduced to nitrites before to beginning of colour reaction. The described research method is recognized and widely used in assays to determine the content of nitrates and nitrites in vegetables.

Statistical analysis

All analyses were carried out in three parallel replications (n = 3) and standard deviations (SD) were calculated for the obtained mean values. The single-factor analysis of variance has been used to find the significance of differences between the

mean values of the parameters investigated for the vegetable stored in two different types of package. The two-factor analysis of variance was employed to establish the significance of differences between values of the parameters evaluated for the chilled-stored vegetable depending on the package type used and length of chilled storage. The Statistica 9.1. PL program was applied for all the calculations made. In order to evaluate the significance of differences at the critical significance level of $p \leq 0.05$, the Duncan's multiple range test has been used.

Results

As the dry matter content in pickled cucumbers depending on the process applied and the container used, all the results presented below along with conclusions have been discussed basing on the results calculated per the dry matter unit. In consequence, only an effect of the process applied was shown.

Vitamin C

Fresh vegetables (before packaging) contained 243 mg of vitamin C per 100 g of dry matter (Table 1). In the vegetables which were cold stored for the successive 4 months, the losses in vitamin C were statistically significant ($p \leq 0.05$) and were respectively: 17.3; 24.4; 23.4 and 26.1% in the PE-LD bags; and 24.0; 26.4; 24.3, and 27.5% in the PET met/PE bags, compared to the vegetable prior to packaging.

Table 1

The content of vitamin C in cold-stored pickled cucumbers [mg/100 g d.m.]

The kind of processing	Vitamin C	
Before storage	$243^{a} \pm 40$	
Cool storage	The kind of packaging	
	Zipper seal bags (PE-LD)	Bags (PET met/PE)
1 month	$201^{ab} \pm 24$	$184.6^{b} \pm 1.5$
2 months	$183.6^{b} \pm 1.3$	$178.9^{b} \pm 1.0$
3 months	$186.2^{b} \pm 1.9$	$183.94^{b} \pm 0.26$
4 months	$179.7^{b} \pm 1.1$	$176.20^{b} \pm 0.77$
Mean value for packaging	$199^{A} \pm 26$	$193^{A} \pm 28$

Values are presented as mean value ± standard deviation.
The values denoted with the same letters do not differ statistically significantly at $p \leq 0.05$.

It has been proved that, the type of package had no statistically significant ($p > 0.05$) effect on vitamin C content in the cold stored pickled cucumbers.

Total polyphenols

The content of total polyphenols in the examined fresh vegetables has been expressed as chlorogenic acid equivalent and was 1202 mg CGA/100 g d.m. (Table 2).

Table 2

The content of total polyphenols in cold-stored pickled cucumbers [mg CGA/100 g d.m.]

The kind of processing	Total polyphenols	
Before storage	$1202^{a} \pm 19$	
Cool storage	The kind of packaging	
	Zipper seal bags (PE-LD)	Bags (PET met/PE)
1 month	$1103^{d} \pm 15$	$1178^{b} \pm 18$
2 months	$1104.6^{d} \pm 7.0$	$1151.3^{c} \pm 7.4$
3 months	$1056^{f} \pm 25$	$1083.1^{de} \pm 8.4$
4 months	$1070^{ef} \pm 16$	$1094^{d} \pm 2.7$
Mean value for packaging	$1107^{B} \pm 57$	$1142^{A} \pm 52$

Values are presented as mean value ± standard deviation.
The values denoted with the same letters do not differ statistically significantly at $p \leq 0.05$.

In comparison with vegetables prior to packaging, in successive 4 months losses in total polyphenols in the cold-stored vegetables were respectively: 8.2; 8.1; 12.2 and 11.0% for the PE-LD bags and 2.0; 4.2; 9.9 and 8.9% for the PET met/PE bags; these losses were statistically significant ($p \leq 0.05$).

Studies revealed that the type of package which was used to store pickled cucumbers under chilling conditions, significantly affected ($p \leq 0.05$) the content of total polyphenols in the product. In pickled cucumbers stored in the PET met/PE bags, a decrease in polyphenol content was significantly lower ($p \leq 0.05$) compared to the cucumbers kept in PE-LD bags with the zipper closure.

Antioxidant activity

Antioxidant activity in fresh vegetable was 26.90 μm Trolox eq./1 g dry matter (Table 3).

Statistically significant changes in antioxidant activity ($p \leq 0.05$) occurred after only 1-month chilled storage of pickled cucumbers, when antioxidant activity decreased to 23.92 (by 11.1%) in the vegetables stored in PE-LD bags and to 24.52 μm Trolox eq/1 g d.m. (by 8.8%) in those kept in PET met/PE bags, compared with vegetables before packaging. Throughout the next 3 months of chilled storage, further significant ($p \leq 0.05$) losses in antioxidant activity were observed: of 11.9; 13.6 and 12.9% respectively in vegetables packed in PE-LD bags; and of 10.3; 12.9 and 12.6% in

Table 3

Antioxidant activity of cold-stored pickled cucumbers [μm Trolox/1 g d.m.]

The kind of processing	Antioxidant activity	
Before storage	$26.90^{a} \pm 0.52$	
Cool storage	The kind of packaging	
	Zipper seal bags (PE-LD)	Bags (PET met/PE)
1 month	$23.92^{cd} \pm 0.16$	$24.52^{b} \pm 0.20$
2 months	$23.71^{cde} \pm 0.29$	$24.12^{bc} \pm 0.00$
3 months	$23.23^{g} \pm 0.23$	$23.44^{fg} \pm 0.12$
4 months	$23.44^{fg} \pm 0.11$	$23.52^{def} \pm 0.09$
Mean value for packaging	$24.3^{A} \pm 1.5$	$24.5^{A} \pm 1.4$

Values are presented as mean value ± standard deviation.
The values denoted with the same letters do not differ statistically significantly at $p \leq 0.05$.

vegetables stored in meth PET met/PE pouches compared with vegetables analyzed prior to packing (Table 3).

The type of package had no significant ($p > 0.05$) effect on antioxidant activity of cold-stored pickled cucumbers.

Nitrates

Nitrates were determined according to the Polish Standard and the results were expressed as the amount of NO_3^- nitrate ions per kg of dry matter. The content of nitrates in fresh vegetables was 234 mg NO_3^-/kg d.m. (Table 4).

Table 4

The content of nitrates in cold-stored pickled cucumbers [mg/kg d.m.]

The kind of processing	Nitrates (NO_3^-)	
Before storage	$234^{d} \pm 23$	
Cool storage	The kind of packaging	
	Zipper seal bags (PE-LD)	Bags (PET met/PE)
1 month	$224.8^{d} \pm 1.9$	$246^{d} \pm 29$
2 months	$828^{bc} \pm 40$	$863^{b} \pm 56$
3 months	$779^{c} \pm 15$	$839^{bc} \pm 44$
4 months	$946^{a} \pm 15$	$1011^{a} \pm 30$
Mean value for packaging	$602.5^{A} \pm 345.8$	$638.9^{A} \pm 369.8$

Values are presented as mean value ± standard deviation.
The values denoted with the same letters do not differ statistically significantly at $p \leq 0.05$.

After 1-month storage, the amount of nitrates in pickled cucumbers changed in both types of package; however, this difference was statistically insignificant ($p > 0.05$). The level of nitrates in vegetables stored in PE-LD bags fell to 224.8 mg NO_3^-/kg dry matter (by 3.9%), while in those packed in Pet met/PE bags increased up to 246 mg NO_3^-/kg dry matter (by 5.1%) compared to the vegetable before packing.

A significant ($p \leq 0.05$) increase in the level of nitrates in pickled cucumbers which were chilled stored in two types of package, occurred in the subsequent three months; in the vegetables stored in the PE-LD bag increased by 253.8; 232.9 and 304.3% respectively; and in the second type of package, which were the PET met/PE bags, by 268.8; 258.5 and 332.0% compared to the vegetables prior to packaging.

The type of the packing was found to have no significant ($p > 0.05$) effect on the nitrates content in pickled cucumbers stored under chilling conditions.

Nitrites

The results referring to the content of nitrites were presented as calculated on nitrite ions (NO_2^-) per kg fresh and dry matter. The content of nitrites in the fresh vegetable was 15.3 mg NO_2^-/kg dry matter (Table 5).

Table 5

The content of nitrites in cold-stored pickled cucumbers [mg/kg d.m.]

The kind of processing	Nitrites [NO_2^-]	
Before storage	$15.3^{e} \pm 3.6$	
Cool storage	The kind of packaging	
	Zipper seal bags (PE-LD)	Bags (PET met/PE)
1 month	$12.34^{e} \pm 0.72$	$14.4^{e} \pm 2.3$
2 months	$35.4^{cd} \pm 2.6$	$39.3^{bc} \pm 4.9$
3 months	$31.7^{d} \pm 2.0$	$37.3^{cd} \pm 3.2$
4 months	$45.1^{b} \pm 1.0$	$51.9^{a} \pm 2.1$
Mean value for packaging	$28^{A} \pm 14$	$31^{A} \pm 16$

Values are presented as mean value ± standard deviation.
The values denoted with the same letters do not differ statistically significantly at $p \leq 0.05$.

After a period of 1-month chilled storage, the amount of nitrites in pickled cucumbers decreased in both types of package, although, the differences were not statistically significant ($p > 0.05$) compared to the vegetables prior to packaging.

Compared to the vegetable before packaging, the content of nitrites in the vegetables stored in PE-LD bags decreased up to 12.34 mg NO_2^-/kg dry matter (by 19.3%), whereas in those kept in PET met/PE bags up to 14.4 mg NO_2^-/kg dry matter (by 5.9%).

As in the case of the nitrates, in successive months of chilled storage there was a substantial statistically significant ($p \leq 0.05$) increase in the content of nitrites in pickled cucumbers: of 131.4, 107.2, and 194.8% respectively for those stored in PE-LD bags; and of 156.9, 143.8, and 229.2% respectively for those from the second type of package (PET met/PE bags), compared to the vegetables prior to packaging. Studies showed that the type of package, in which pickled cucumbers were chilled stored, had no effect ($p > 0.05$) on the content of nitrites.

Discussion

Vitamin C

Vitamin C content in vegetables depends on several factors but mainly on the cultivar, stage of maturity at harvest, site and method of cultivation, agro-technique, climatic conditions, storage, as well as technology of processing and preservation [9]. The content of vitamin C in the fresh cucumber ranges in 4.6–10.8 mg/100 g fresh matter depending on the method and the year of cultivation [10] or from 9.19 to 11.15 mg/100 g fresh vegetable, as was reported by Jarosz et al [11].

In this work, pickled cucumbers prior to packing contained 12.5 mg vitamin C that do not correspond to the data available in the literature. According to the "Great tables of calories and nutritional value of food", the pickled cucumber has only 2 mg vitamin C, while in accordance with "Nutritional value of selected food products and typical dishes" this value is 4 mg/100 g fresh vegetable [12–13].

Chilled storage of vegetables causes a decrease in vitamin C content and the extent of degradation depends on its initial content in every vegetable. Compared to the raw vegetable, great losses of vitamin C (up to 80%) after 3-month chilled storage, were reported by Hounsome et al [9], who conducted similar studies but on white cabbage. On the other hand, Grzesiuk and Gorecki [14] observed small losses of this vitamin in white cabbage; after 6-month chilled storage, the losses recorded were only of 18%. Falls in vitamin C content due to chilled storage were also confirmed by the findings of Kmiecik and Lisiewska [15], who examined marinated paprika and Wojdyla et al [16], who investigated marinated pumpkin.

Acidic environment, as the only one, stabilizes the level of vitamin C. Pickled cucumbers have acidic pH ranging in 3.4–4.0 [17]. These studies revealed a sharp decline in vitamin C after 1 month of storage and milder after the second month; the level of this vitamin has stabilized only after third and fourth month of chilled storage. A fall in vitamin C content in stored vegetables could result from temperature fluctuation throughout the process discussed [18]. Losses in vitamin C may also be caused by previous technological operations such as: peeling, cutting, which lead to enzymatic decomposition of this substance or its exposure to oxygen [19]. The process of cucumber preservation generally causes a decrease in vitamin C content. However, as the solution contains more vitamin C, a direct contact surface cucumber/solution should be created in order to reduce such losses. In view of the above, cutting off cucumber ends may be a good method of vitamin C stabilization [17].

The package type has also an effect on losses in vitamin C in the chilled stored vegetables. In the case of broccoli which was chilled stored for 6 days in intended to come into contact with food open plastic boxes, Nath et al [20] recorded vitamin C losses of as much as 72%, while in the vegetables packed hermetically in polypropylene (PP) foil the losses were much smaller, amounting to 29.2%.

There was no data on the impact of the packaging type used in this work on changes in the content of vitamins in pickled cucumber.

Total polyphenols

In the pickled cucumbers examined in this work, total polyphenols amounted to 61.8 mg (expressed as chlorogenic acid – CGA) per 100 g fresh matter of the vegetable. However, since there is no literature data referring to pickled cucumbers, the results have been compared to fresh cucumber, in which Kevers et al [21] registered, on average, 20 mg total polyphenols (expressed as chlorogenic acid); the values reported by Ciz et al [22] and Chu et al [23] were respectively 24.2 mg and 14.37 mg per 100 g fresh matter of the vegetable (expressed as gallic acid). On the other hand, the content of total polyphenols, when expressed as caffeic acid, was 18.9 mg per 1 g fresh matter, as was reported by Ninfali et al [24].

The level of total polyphenols in vegetables depends on several factors such as, for example, genetic, environmental or technological. Preliminary treatment of vegetables (peeling and cutting) leads to enzymatic decomposition of these substances or their decomposition due to the presence of oxygen. In addition, the long-term storage intensifies the processes of enzymatic or chemical oxidation of these substances to an extent depending on environmental factors such as, among others, temperature, pH, water activity, time and the access to oxygen [25]. According to Vina and Chaves [26], a degree of reduction in the level of chlorogenic acid in the celery leaves stored at 10^{o}C and 4^{o}C was three and two times greater respectively than in those stored at 0^{o}C.

A fall in total polyphenols in the chilled stored vegetables may result from the temperature variations during the process. Some of the factors, however, can be controlled to optimize the concentration of total polyphenols. Effect of chilled storage may also depend on the type of vegetable. According to the literature data, the number of total polyphenols may remain unchanged (yellow pepper), increase (tomato, broccoli) or can decrease (lettuce, celery) [19, 21]. As was reported by Bunea et al [27], 24-hour storage of spinach at 4^{o}C caused a 7.6% reduction in these constituents, while after 72-hour storage the losses were greater and amounted to 11.2%. Packaging of the product stored is another important factor to be considered. There was not found even a 1% fall in the level of polyphenols in the broccoli packed in the polypropylene (PP) foil and stored at 5^{o}C for 7 days; whereas, a considerable decrease (of about 27%) was noted in broccoli stored under identical conditions but unpacked [28].

In this study, pickled cucumbers stored in PET met/PE bags was characterized by significantly higher polyphenol content compared with vegetables stored in bags made from PE-LD. There was no evidence on the impact of the packaging type used in this study on changes in the content of polyphenols in pickled cucumber.

Antioxidant activity

In this work, antioxidant activity in pickled cucumbers prior to their packaging was 1.4 μm Trolox eq/1 g fresh matter of the vegetable. However, as there is no the literature on the antioxidant activity of pickled cucumber, the results obtained in this work for antioxidant activity, as in the case with total polyphenols, were compared with the antioxidant activity of fresh cucumber. According to Cao et al [29], antioxidant activity of cucumbers ranged from 0.5 to 3.8, while this recorded by Pellegrini et al [30] was 0.43 μm Trolox eq/1 g fresh matter of the vegetable. Other authors found that antioxidant activity of fresh cucumbers, was 1.82 [24], 1.60 [21], and 1.20 μm Trolox eq./1 g fresh vegetable [22]; however, these values were determined by means of an ORAC method.

Preliminary processing of vegetables (peeling, cutting or comminuting) reduces antioxidant activity of from 20 to even 60% compare to the raw material; this is probably due to the action of enzymes (polyphenoloxidase) and the presence of oxygen [31]. Chilled storage of vegetables causes changes in the levels of antioxidants and induces their mutual interactions, which in turn leads to difficult to predict differences in antioxidant activity. Kevers et al [21] observed either an increase in this parameter (garlic, yellow paprika, broccoli) or a decrease (spinach, lettuce, leek, celery) depending on the vegetable examined. The nature of such changes is also affected by the processes applied and the additives used and is additionally associated with the oxidation-reduction reactions occurring among antioxidants. Storage, among other factors, has an effect on an increased enzymatic or chemical oxidation of polyphenols, which significantly affect antioxidant potential of the analyzed vegetables [19].

Murcia et al [32] found that chilled stored vegetables (lettuce, broccoli, and Brussels sprouts) lost about 30–40% their initial antioxidant activity after only 1-week chilled storage, while cucumber only 0.9%. The greater losses (up to 53.8%) in antioxidant activity in chilled stored broccoli were recorded by Nath et al [20].

Temperature of chilled storage of vegetables may also have an effect on their antioxidant activity, since, as reported Javanmardi and Kubota [1], antioxidant activity of tomatoes stored for one week at 5^{o}C was 1.77 higher than those kept at 12^{o}C.

However, there is no research in the available literature dealing with the effect of packaging on antioxidant activity of the chilled stored vegetables.

Nitrates and nitrites

Vegetables and vegetable products provide about 80% of nitrates in the daily food ration. These are substances of low-toxicity and most of them, in an unchanged form, are excreted from the body with urine. Part of them, however, is converted into the toxic nitrites in the gastrointestinal tract. So, the level of nitrites results from the content of nitrates. Hence, both of these constituents will be discussed together [4].

As there is no the literature concerning the contents of nitrates and nitrites in pickled cucumbers, the results obtained will be confronted with those for fresh cucumbers.

In the present study, the amount of nitrates determined in the pickled cucumbers prior to their packaging was 12.1 mg NO_3^-/kg fresh vegetable (321.3 mg $NaNO_3$/kg fresh matter). A slightly lower value, varying from 9.25 to 9.38 mg NO_3^-/kg fresh vegetable mass, was registered by Gajc-Wolska et al [33]. The result of 313.1 mg $NaNO_3$/kg fresh vegetable mass, registered by Tietze et al [34], was very similar to the result obtained in the present work; although, the levels of nitrates in cucumbers determined by Pirog et al [35], fluctuated broadly from 86.0 to 539.3 mg $NaNO_3$/kg fresh vegetable mass.

Existing legislation, such as the obligatory EC Regulation of 2011, sets maximum acceptable levels for nitrates only in selected vegetables such as fresh, preserved, and frozen spinach, fresh lettuce, rucola and Iceberg-type lettuce; the level of nitrites was not set [36].

In vegetables, the degree of nitrates accumulation depends on several factors, of which crucial are genetics, species, and the cultivar. Taking into account the ability to accumulate nitrates, vegetables can be divided into 3 groups: the first (tomato, cucumber, beans) accumulates small amounts; the second (carrots, celery leaves) gains moderate quantities; and the third (lettuce, spinach, and early cabbage) accumulating substantial quantities of such nitrates. The level of nitrates is also affected by the stage of maturity (young plants are abundant in these substances); type of soil and its pH (heavy soils, along with low pH of soli favour the accumulation of nitrate ions); fertilization (dose, form of nitrogen, and manner of fertilization); exposure to the sun's rays (a small amount of light elevates the level of nitrates); and water availability (during drought larger quantities are accumulated) [34, 37]. Their increase is also influenced by the presence of microelements in soil, particularly by the deficiency of molybdenum. Storing of the raw material under appropriate conditions is also essential, since too high temperature and oxygen deficiency may lead to unfavourable bio-chemical processes, which have an effect on the levels of nitrates [38].

The findings of Lisiewska and Kmiecik [39] revealed that the content of nitrates in vegetables from *Cucurbitaceae* family depends on edible part of vegetable. It has been found that when the cucumber length was rising, the content of nitrates was falling. When storing vegetables, physical, microbiological and biochemical changes, occurring in this period, have an effect on their chemical composition, including changes in the nitrates content.

In the present work, the level of the nitrites was found to be 0.8 mg NO_2^-/kg fresh matter (1.2 mg $NaNO_2$/kg fresh matter) and this result is congruent with the findings of Hou et al [4], who examined pickled cucumbers. The results obtained from 25 samples ranged from 0.14 to 9.36 mg NO_2^-/kg fresh vegetable matter of the vegetable. On the other hand, Pirog et al [35] revealed that this value was within the range 0.01–0.15 mg $NaNO_2$/kg fresh matter of the vegetable.

Ezeagu [40] conducted studies on differences in the levels of nitrites and nitrates in ogi, which is maize-fermented porridge originated from Nigeria, throughout its 8-day storage at room temperature. The author found an about 80% reduction in nitrates, while the level of nitrites increased of about 200% compared to the not stored porridge.

Throughout the period of chilled storage of vegetables, accumulation of nitrates may, although non-necessarily, be inhibited. Inadequate storage conditions may lead to an increase in bacteria containing the enzyme nitrate reductase contributing to the conversion of nitrates and other nitrogen compounds into nitrites and thereby to an increase in the content of nitrites in vegetables [4].

The studies of Niewczas et al [37] on changes in nitrates in the *Cucurbita maxima* pumpkin proved that 3-month storage reduced their level by 62.2% compared to the initial quantities; however, no differences were found in the content of nitrites. These studies showed that the levels of both nitrates and nitrites increased considerably.

In chilled stored vegetables, a package has an effect the content of nitrates and nitrites. Pickled vegetables (turnip, cucumber, and cabbage), which were chilled stored in hermetic plastic containers, contained significantly less nitrites (the mean value for all the vegetables examined: 2.73 mg NO_2^-/kg fresh matter) than the same vegetables stored without packaging (6.08 mg NO_2^-/kg fresh matter) [4].

There was no data on the impact of the packaging type used in this work on changes in the content of nitrates and nitrites in pickled cucumber.

Conclusions

This work revealed that, compared to the vegetables before packaging, a 4-month period of chilled storage of vegetables led to a decrease in the content of vitamin C, total polyphenols, as well as a fall in antioxidant activity, which was accompanied by an increase in the levels of nitrates and nitrites, regardless of the package used. The differences were statistically significant ($p \leq 0.05$).

These studies proved also that type of the package used had no statistically significant ($p > 0.05$) effect on the content of vitamin C, nitrates and nitrites as well as antioxidant activity in cold-stored pickled cucumbers.

It has been found that a decrease in total polyphenols in pickled cucumbers stored in PET met/PE bags was smaller compared to those stored in PE-LD bags with the zipper closure and these values were statistically significant ($p \leq 0.05$).

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WPŁYW OPAKOWANIA NA JAKOŚĆ ZDROWOTNĄ OGÓRKÓW KISZONYCH CHŁODNICZO SKŁADOWANYCH

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Abstrakt: W związku z nietrwałością przechowalniczą ogórków i ich sezonowością jedną z najkorzystniejszych metod ich utrwalania jest kiszenie. Celem niniejszych badań przeprowadzonych w 2014 r. było zbadanie wpływu rodzaju opakowania (torebki wykonane z folii polietylenowej o małej gęstości (PE-LD) oraz torebki z metalizowanego politereftalanu etylenu (PET met/PE) na wybrane parametry jakościowe ogórków kiszonych. Analizy były wykonywane w warzywach przed zapakowaniem oraz po 1-, 2-, 3- i 4-miesięcznym okresie chłodniczego składowania w dwóch rodzajach opakowań. Badania nie wykazały istotnego statystycznie ($p > 0,05$) wpływu rodzaju użytego opakowania na zawartość witaminy C, azotanów(V), azotanów(III) oraz na aktywność antyoksydacyjną przechowywanych w nich chłodniczo ogórków kiszonych. Istotnie statystycznie ($p \leq 0,05$) wyższą zawartością polifenoli ogółem odznaczały się ogórki kiszone przechowywane w woreczkach z folii metalizowanej.

Słowa kluczowe: przechowywanie chłodnicze, opakowania strunowe z PE-LD, opakowania metalizowane PET/met/PE, azotany(V), azotany(III), ogórki kiszone, witamina C, aktywność antyoksydacyjna