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THE INFLUENCE OF ANTIOXIDANT POSTHARVEST TREATMENT ON CONTENT OF BIOLOGICALLY ACTIVE SUBSTANCES DURING STORAGE OF CUCUMBERS

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Abstract. The influence of heat treatment with antioxidant compositions on the content of biologically active substances during storage of cucumbers is investigated. It was found that the use of the proposed treatment inhibits the activity of ascorbate oxidase by 15–18%, which allows to slow down the decomposition of ascorbic acid by 1.5 times. The content of ascorbic acid in the experimental fruit after storage for 28 days is 1.4 times higher than in the control after 21 days of storage. It was found that in the cucumbers 11–14 sm long, the synthesis of polyphenols continued in the period of storage. The intensity of accumulation of phenolic substances proved to be different in the treated and control groups. It was shown that thermal treatment with antioxidants slowed the growth rate of total polyphenols by 20% relative to control, indicating inhibition of maturation processes. It was revealed that the activity o polyphenol oxidase during the storage of treated fruits was slowing down. It has been established that the application of said treatment substantially inhibits the degradation of chlorophylls. Rapid loss of chlorophyll caused yellowing and loss of consumer properties in the control groups after 2 weeks of storage. In processed cucumbers only 21 days of storage revealed a decrease in the concentration of chlorophyll in relation to the moment of laying. At day 28 the amount of chlorophylls in the experimental fruit is at the same level as in the control after a week of storage. It has been found that the use of the proposed treatment slows the degradation of carotenoids. The quantity of carotenoids in experimental cucumbers at the end of storage is 21–23% higher than in the control ones. The compensatory function of ascorbic acid, carotenoids and phenolic substances during storage of cucumber fruits is proved.

Key words: storage of cucumbers, phenolic substances, ascorbic acid, carotenoids, chlorophylls, polyphenol oxidase, ascorbate oxidase.

ВПЛИВ ПІСЛЯЗБИРАЛЬНОЇ ОБРОБКИ АНТИОКСИДАНТАМИ НА ВМІСТ БІОЛОГІЧНО АКТИВНИХ РЕЧОВИН ВПРОДОВЖ ЗБЕРІГАННЯ ОГІРКІВ

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Анотація. Досліджено вплив післязбиральної обробки антиоксидантними композиціями на вміст біологічно активних речовин під час зберігання огірків. Виявлено, що використання запропонованої обробки гальмує на 15–18% активність аскорбатоксидази, що дозволяє в 1,5 рази сповільнити розпад аскорбінової кислоти. Вміст аскорбінової кислоти в дослідних плодах після зберігання протягом 28 діб в 1,4 рази вищий, ніж в контрольних після 21 доби зберігання. Показано, що післязбиральна обробка антиоксидантами сповільнює темпи зростання поліфенолів на 20% відносно контролю, що свідчить про інгібування процесів дозрівання. Встановлено, що застосування зазначеної обробки істотно інгібує деградацію хлорофілів. В оброблених огірках лише на 21 добу зберігання виявлено зниження концентрації хлорофілів по відношенню до моменту закладання. На 28 добу сума хлорофілів в дослідних плодах знаходиться на тому ж рівні, що і в контрольних через тиждень зберігання. Виявлено, що використання запропонованої обробки сповільнює деградацію каротиноїдів. Кількість каротиноїдів у дослідних огірках на кінець зберігання на 21–23% більша, ніж в контрольних. Доведено компенсаторну функцію аскорбінової кислоти, каротиноїдів і фенольних речовин під час зберігання плодів огірка.

Ключові слова: зберігання огірків, фенольні речовини, аскорбінова кислота, каротиноїди, хлорофіли, поліфенолоксидаза, аскорбатоксидаза.

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Introduction. Formulation of the problem

Numerous research of the population health status conducted by leading healthcare experts showed that diet violations lead to the development of structural and functional changes in a body, disorder of metabolic processes, trophic homeostasis as well as its protective reserves [1,2]. The retrospective analysis suggests the alimentary diseases having a steady upward trend within the recent decades [3,4].

The negative influence of the environment, prevalence of deceased and stressful conditions of people stipulate the need to enrich the diet with fruit and vegetable products with high content of biologically active substances. The yielding of fruit and vegetable products is increasing on the world agrarian market. Its structure is currently comprised of about 20% of fruits and more than 50% of vegetables [5].

The gross level of vegetable production both in the world and in Ukraine shows the positive dynamics towards the increase of the volumes of yield. The calculation of the vegetable crops per capita has convincingly demonstrated the indications of the vegetable crops increment: in 1990 the world market received 88 kg of vegetables per capita, while in 2010 this indication constituted 138 kg [6]. In Ukraine, during the permanent financial crisis, vegetable growing is becoming a major factor in supplying products with high nutritional value and biological value to the population at affordable prices.

Cucumbers occupy a significant part (10%) in the structure of vegetable production in Ukraine [6]. The increase of the planted areas under this crop is facilitated by its early ripening, high profitability, and consumer demand. According to FAOSTAT, Ukraine is ranked sixth in the classification of world cucumber producers [7]. The annual rate of consumption of vegetables per person is 161 kg, of which cucumbers take15.5 kg [8].

The stable demand for the fruits of this cucurbits crop throughout the year is due to their high taste and dietary characteristics. Cucumbers contain about 96% water, insignificant amount of fibers and are characterized by a reduced energy value. The level of dry matter in them is in the range of 3,0–6,0% [9]. Cucumbers are rich in biologically active substances: vitamins A, B, C and K, polyphenols, flavonoids, tannins, chlorophylls, lutein, β-carotene, as well as minor nutrient elements: potassium, magnesium, phosphorus, calcium; they contain glycosides, steroids [10–12]. Polyphenols of cucumbers are represented by flavonols, cumaric, cinnamic and caffeic acids [13].

Analysis of recent research and publications

Demand for fresh cucumbers is steadily high throughout the year [14]. However, in the diet of the population, there is a significant seasonal shortage of cucumbers. High-priced imported products are predominantly at retail [15]. Domestic cucumber production, despite the general trend of yield growth, is constrained by the lack of efficient cold storage technologies [16]. In order to meet the needs of all market actors, there is a need for research in the direction of extending the duration of storage of cucumber fruits and preservation of their biologically active substances.

Cucumbers are heat-loving crops, therefore they are characterized by the low adaptive potential for cold [17]. The development of oxidative stress in fruits during cold storage causes the proliferation of intracellular destructive processes and, as a consequence, physiological disorders, disintegration of biologically active substances and loss of quality [18, 19].

The chemical treatment with exogenous antioxidants proved to be effective in preventing the damage of fruits by cold [20–22]. They complement the internal mechanisms of anti-radical protection and suppress the oxidation reaction [23]. Thermal procedures determine the formation of protective proteins of thermal shock, which, in turn, prevent the damage of cellular compartments from oxidative stress [18,24–26]. Positive effect was found when combining chemical treatment with heat treatment of fruits, the synergy of their effects increases the internal mechanisms of resistance to stress [27–29].

The novelty of the scientific work is that the cucumbers have not been investigated in such a perspective so far. It is still unresolved, though, how the fruits respond to this postharvest treatment. Further studies are required for the full understanding of the effect of heat treatment with antioxidants on the preservation of biologically active substances of cucumbers. The obtained results will promote the development of innovative methods for processing cucumbers before storage and dissemination of their practical application. This confirms the relevance of the chosen research direction.

The conducted research **is aimed** at determining the effect of postharvest treatment with solutions of antioxidant compositions on the content of biologically active substances during the storage of cucumbers.

To achieve the selected aim, the following **objectives** were set:

1. To analyze the dynamics of ascorbic acid, phenolic substances, chlorophylls, carotenoids during the storage of cucumbers.
2. To analyze the dynamics of activity of ascorbate oxidase, polyphenol oxidase during the storage of cucumbers.

Research Materials and Methods

The research was carried out within the period 2005-2015 on the basis of the Laboratory of Processing and Storage Technology of Agricultural Products at the Research Institute of Agro-Technologies and Ecology of Tavria State Agrotechnological University (Ukraine). Cucumbers Masha F1 and Athena F1 were studied. Intact fruits 11–14 cm long were laid for storage. Fruits were immersed into antioxidant compositions at the temperature of 42 º C for 10 minutes. The temperature and duration of heat treatment were accepted on the basis of the literary data [30]. The solutions contained chlorophyllipt (Ch), ionol (I) and lecithin (L) [31]. Cucumbers were dried and put in boxes, lined with a plastic film and stored at the temperature of±0.5ºC and the relative humidity of 95±1%. Raw fruits were taken for control.

Indicators of chemical composition were determined according to the following methods:

- the content of phenolic substances in mg/100 g, using the Folin-Denis reagent, according to [32];
- the content of chlorophylls and carotenoids in mg/100 g, by means of extraction with acetone, followed by determination thereof by the spectrophotometric method [33];
- ascorbic acid content in mg/100 g, according to the restoration of Tillmans' reagent [33].

The activity of enzymes was determined by means of the following methods:

- ascorbate oxidase activity, according to the rate of vitamin C oxidation, by iodometric titration, in µmol AA/g×min [34];
- polyphenol oxidase activity, by means of titration of the unreacted vitamin C residue in the oxidation of pyrocatechin in µmol AA/g×min [35].

Results of the research and their discussion

For all the sources of active forms of oxygen in a cell, an individual mechanism of protection was formed. Despite the fact that hydroxyl radicals, singlet oxygen, peroxynitrite and some other radicals actively oxidize the protein molecules, they can not be removed by protein catalysts [34]. Thus, the role of absorbers of highly reactive oxygen intermediates is played by low molecular weight antioxidants, namely, ascorbic acid (AA), polyphenols and carotenoids.

Within the period of research, there was no statistically significant difference in the accumulation of AA with different hybrids. No varietal specificity was established in the dynamics of AA during storage. From the moment of placement in storage, there has been active linear decrease in the level of AA in all variants (Fig. 1).

The reduction of the content of AA in control groups was rapid. Within the first week of storage, the content of AA reduced by 15%. And by the 21st day, the amount of vitamin C became 2.1 times less than the original value.

Loss of AA is related to the enzyme metabolism and the oxidative action of ascorbate oxidase (AAO). AAO in cucurbits crops is the most active. This is explained by its participation in the division and intensive cell growth during maturation [36]. AAO activity is maximal in zucchini, slightly lower in cucumbers, while in melons and pumpkins it is minimal [37].

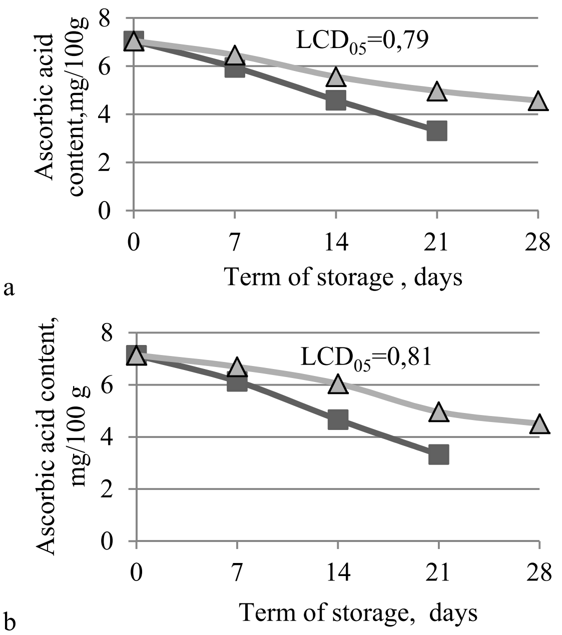

Fig.1. Dynamics of ascorbic acid content in carrots: a – Athena; b – Masha; – control; – heat treatmentCh+I+L

The use of postharvest treatment with antioxidants provides effective retardation of AAO activity (by 15–18%, depending on the hybrid), which allows 1.5 times retardation of AA losses (Fig. 2).

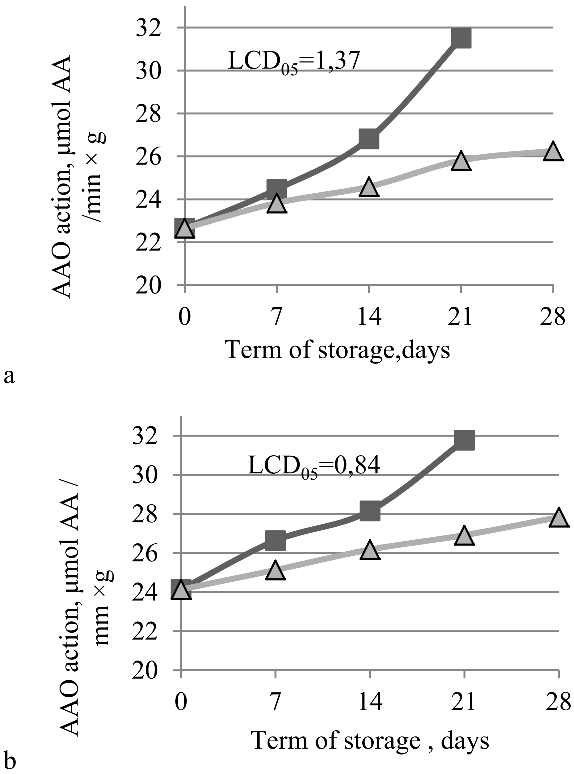

Fig. 2. Dynamicsof ascorbate oxidase in cucumbers: a – Athena; b – Masha; – control; – heat treatmentCh+I+L

During the storage period (28 days) the concentration of AA in the treated variants on average decreased by 1.5 times with regard to the initial value. The level of AA in experimental groups after storage for 28 days was 1.4 times higher than in control ones after 21 days of storage.

It was found that there was a decrease in the level of phenolic substances in the cucumbers 9 ... 11 cm long during the period of storage [38]. By contrast, in the fruit 11–14 cm long, during the storage period the ability to synthesize polyphenols, such as lignin and suberin, which is a characteristic property of cucurbits crops, disappeared [39]. Studies have shown that cucumbers consistently accumulate total phenolic substances with the difference only in the intensity of this process in the treated and control variants (Fig. 3).

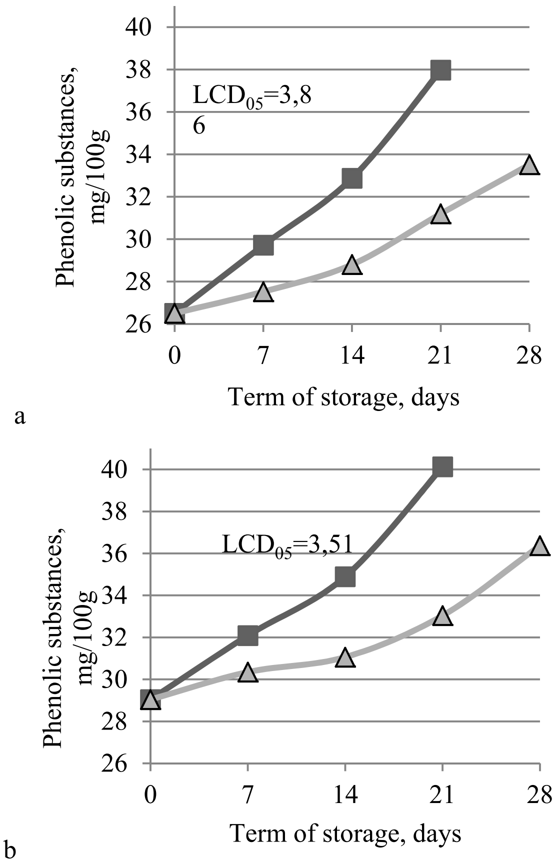

Fig. 3. Dynamics of phenolic substances quantity in cucumbers:
a – Athena; b – Masha; – control; – heat treatmentCh+I+L

Postharvest treatment of fruits with antioxidants inhibited the activity of polyphenol oxidase (PPO) at the beginning of storage (up to 14 days), which is a natural reaction to the effect of high temperature at the time of treatment [40]. The activity of PPO of the experimental fruit is further reduced.

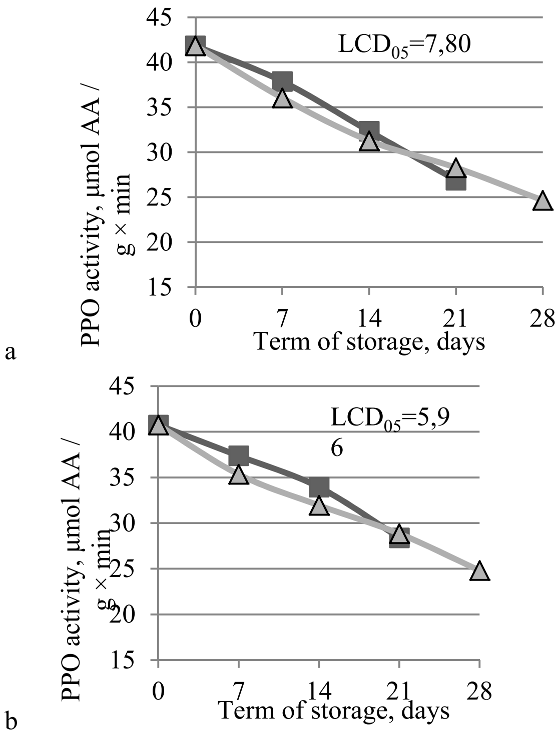

Fig. 4. Dynamics of the activity of polyphenol oxidase in cucumbers:
a – Athena; b – Masha; – control; – heat treatmentCh+I+L

In general, postharvest treatment of fruits with antioxidants showed its effect in inhibiting the growth of total polyphenols by 20% compared with control, which indicates a slowdown in afterripening processes.

Varietal differences in the level of chlorophylls are not significant (Fig. 5). During the storage of the two hybrids control fruits, the loss of chlorophylls is 15% after a week of storage, and it has increased to 35% by the end of the storage period. Rapid loss of chlorophyll causes yellowing and loss of consumer properties in control variants after 2 weeks of storage.

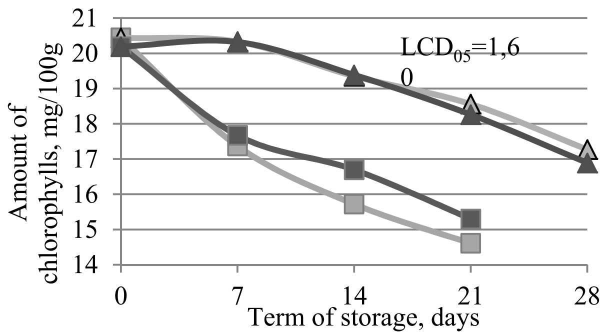

Fig.5. Dynamics of chlorophylls during the storage of cucumbers:
– Athena, no treatment, – Athena, heat treatmentCh+I+L,
– Masha, no treatment, – Masha, heat treatmentCh+I+L.

Due to the use of antioxidant composition, the decomposition of chlorophylls slows down significantly. In treated variants, a statistically significant reduction of chlorophyll levels relative to the beginning of storage was established only on the 21st day of storage. On the 28th day, the amount of chlorophylls in the experimental groups remained at the same level as in the control ones after 7 days of storage. In this case, the external characteristics of cucumbers meet the requirements of the standard.

The varietal peculiarities of carotenoids formation in cucumbers are leveled during the period of storage. The dynamics of these pigments is reflected in a steady decrease in their content, both in control and experimental groups (Fig. 6).

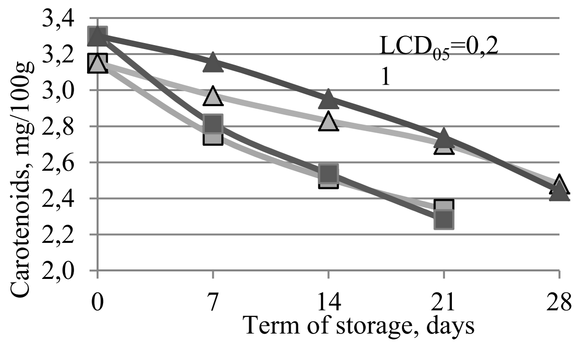

Fig. 6. Dynamics of carotenoids during the storage of cucumbers:
– Athena, notreatment, – Athena, heat treatmentCh+I+L, – Masha, notreatment, – Masha, heat treatmentCh+I+L.

The main cause of carotenoids degradation is their enzymatic and non-enzymatic oxidation. Therefore, the use of antioxidant compositions slows down their destruction. The rate of carotenoids decay in experimental fruits is much lower. At the end of storage, they account for 21–23% more than in the control groups.

Conclusions

In the course of research, the effect of postharvest treatment with solutions of antioxidant compositions on the content of biologically active substances during the storage of cucumbers was established.

Postharvest treatment with antioxidants slowed down the growth rate of total polyphenols by 20% relative to the control, indicating inhibition of afterripening processes. Analysis of the activity of enzymes in treated fruits showed the inhibition of polyphenol oxidase as compared with control samples.

The application of postharvest treatment with antioxidants significantly slows the disintegration of chlorophylls. In the treated cucumbers, a statistically significant reduction in the chlorophyll content relative to the start of placement in storage was established only on the 21st day of the storage. On the 28th day, the content of chlorophylls in the treated fruit remained at the same level as in the control after 7 days of storage.

The use of the proposed treatment inhibits the degradation of carotenoids. The concentration of carotenoids in experimental variants at the end of the storage is 21 ... 23% higher than in the control.

Postharvest treatment with antioxidants slows the activity of ascorbate oxidase by 15 ... 18%. This ensures that the loss of ascorbic acid is inhibited by 1.5 times. The content of ascorbic acid in the experimental fruit after storage for 28 days is 1.4 times higher than the control after the 21st day of storage.

The resulting data determine the expediency of the further research as to the effect of the postharvest treatment with antioxidants on the extension of the storage time of vegetable crops.

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ВЛИЯНИЕ ПОСЛЕУБОРОЧНОЙ ОБРАБОТКИ АНТИОКСИДАНТАМИ НА СОДЕРЖАНИЕ БИОЛОГИЧЕСКИ АКТИВНЫХ ВЕЩЕСТВ ПРИ ХРАНЕНИИ ОГУРЦОв

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Аннотация. Исследовано влияние послеуборочной обработки антиоксидантными композициями на содержание биологически активных веществ при хранении огурцов. Выявлено, что использование предложенной обработки тормозит на 15–18% активность аскорбатоксидазы, что позволяет в 1,5 раза замедлить распад аскорбиновой кислоты. Содержание аскорбиновой кислоты в исследовательских плодах после хранения в течение 28 суток в 1,4 раза выше, чем в контрольных после 21 суток хранения. Показано, что послеуборочная обработка антиоксидантами замедляет темпы роста общих полифенолов на 20% относительно контроля, что свидетельствует об ингибировании процессов созревания. Установлено, что применение указанной обработки существенно ингибирует деградацию хлорофиллов. В обработанных огурцах лишь на 21 сутки хранения выявлено снижение концентрации хлорофиллов по отношению к моменту закладки. На 28 сутки сумма хлорофиллов в исследовательских плодах находится на том же уровне, что и в контрольных через неделю хранения. Выявлено, что использование предложенной обработки замедляет деградацию каротиноидов. Количество каротиноидов в опытных огурцах на конец хранения на 21–23% больше, чем в контрольных. Доказана компенсаторная функция аскорбиновой кислоты, каротиноидов и фенольных веществ во время хранения плодов огурца.

Ключевые слова: хранение огурцов, фенольные вещества, аскорбиновая кислота, каротиноиды, хлорофиллы, полифенолоксидаза, аскорбатоксидаза.

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