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RESEARCH OF GARLIC PRESERVATION DEPENDING ON TREATMENT WITH HYDROPHOBIC PROTECTIVE COATINGS AND GROWTH-INHIBITING SUBSTANCES

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Abstract

The aim of the work was to improve the elements of garlic bulb storage technology by using hydrophobic protective coatings, growth inhibitors. The study allows you to choose protective coatings of garlic bulbs for long-term storage and extend the duration of storage.

It has been found, that the loss of weight of garlic bulbs during storage depends on the method of storage and type of treatment of garlic plants. Weight loss during storage in boxes with polyethylene inserts is reduced by 2 times, bulbs, treated with paraffin, – by 3.4 times. Treatment of plants with maleic acid hydrazide (MAH) reduces weight loss by 1.7 times. After 6 months of storage, the loss due to dry matter ranged from 51.7 to 69.7 % of weight loss.

It has been found, that the treatment of plants by MAH helps to reduce losses due to germination of bulbs, damage by microorganisms, drying compared to the control version and storage in boxes with polyethylene inserts. The highest yield of 91.8 % of commercial bulbs is provided by their treatment with paraffin. Analysis of variance showed that the method of storage affects the preservation of garlic by 98 %, the development of diseases – by 54 %. Treatment by MAH affected the germination of bulbs by 98 %.

Based on the obtained results, a correlation analysis was performed and the linear dependence of the weight loss of winter garlic bulbs depending on the peculiarities of the storage method was established.

Keywords: garlic bulb, storage technology, hydrophobic protective coatings, growth inhibitors.

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1. Introduction

Garlic is usually stored for a long time after harvest until it enters the market. The main problem during storage is water evaporation, germination and development of microorganisms.

The most common way to prevent the germination of vegetables is their storage at low temperatures. The lower the temperature, the slower the synthesis of substances necessary for growth in meristematic tissues and the slower the inhibitors of growth processes are involved in metabolism [1].

A residual agent Restrain (Great Britain) is used against germination on the basis of gaseous ethylene. Ethylene is a natural gas that inhibits the germination of vegetable cells. Dispersion of ethylene according to the exact protocol during the storage period reduces or prevents germination [2].

Onions *(Alliumcepa)* are considered non-climacteric vegetables. However, in onions, ethylene can inhibit germination, while ethylene binding inhibitor 1-methylcyclopropene (1-MCP) can also inhibit sprout growth [3].

The study of the important role of endogenous growth regulators has provided a basis for the search for and use of exogenous growth regulators to inhibit and stimulate growth processes. To avoid losses due to germination during vegetable storage, the anti-germination agent Chlorpropham (CIPC) has been widely used for the last few decades. However, the European Union recently decided not to authorize the renewal of the CIPC, prompting the search for alternative methods. The potential of treating potatoes with maleic acid (MA) before and after harvest against germination to replace CIPC was evaluated. It has been established, that MA treatment is a valuable alternative to CIPC to control potato germination during processing [4].

MAH preparation – maleic acid hydrazide in the form of 0.25–0.30 % aqueous solutions of diethanolamine or sodium salt is used to prevent the germination of food potatoes, roots, onions.

Maleic hydrazide (MH) was used to inhibit sprouts. This study was conducted to find alternative methods to inhibit germination.

The results of treatment of garlic leaves 3 weeks before harvest with protocatechuic acid (PCA) and abscisic acid (ABA) are presented in [5]. Protocatechuic acid (3,4-dihydroxybenzoic acid, 3,4-dioxybenzoic acid, protocatechinic acid, abbreviated from English (PCA, 3,4-DHB, 3,4-DHBA)) is an organic compound, phenolic acid, one of the six isomers of dihydroxybenzoic acid .

The results showed that such treatment and storage in the environment gave the longest shelf life of garlic – 300 days, with 30 % of the preserved bulbs did not germinate. This result indicates the potential of protocatechuic acid and abscisic acid [5].

Simple maleic acid and L-tartaric acid have been shown to be effective sprout inhibitors. Both can prevent germination for up to 6 weeks and 4 weeks after treatment, respectively, at room temperature in the dark. They do not affect the quality parameters, retain moisture and maintain a dense appearance of tubers throughout the shelf life. Thus, maleic acid and L-tartaric acid can be classified as alternative, cheap and effective means of suppressing sprouts during storage and processing of potato tubers [6].

Study [7] describes the storage of potatoes at 25 °C with rosemary leaves and twigs, which led to the least sprout development and weight loss after 10 weeks. This differed significantly from the number of sprouted tubers at a storage temperature of 4 °C or 30 °C. The results showed that fresh rosemary leaves and twigs can improve the shelf life of potatoes, given its simplicity and effectiveness in reducing storage costs, weight loss and germination without any environmental toxicity. In addition, the potential of rosemary can be used for other fruits and vegetables to further explore the possible role of rosemary in preventing fungal rot.

Each drug has its advantages and disadvantages. The purest preparation is MAH, which is sprayed on plants 2–3 weeks before harvest, when the leaves are still green, and the formation of tubers, bulbs, roots is mostly over. Spraying should be carried out within the specified period, as early treatment reduces yields, and late – ineffective.

One of the effective methods of storing fresh fruits, vegetables and products of their processing is the use of various types of packaging and application of protective easily removable coatings. The product is applied directly to the liquids, in which it is immersed, and coatings with or without antimicrobial action. Such protection mainly does not create toxicological problems. However, accidental transfer of packaging and coating components to the food product is not excluded.

A coating based on hydroxypropyl methylcellulose using beeswax, which was applied immediately after harvesting, was developed for plums. Plums with a coating, containing 20, 40 and 60 g/100 g of beeswax were stored for 4 weeks at 1 °C, and then for 1–3 weeks at 20 °C. The addition of beeswax to the coating has been found to reduce its mechanical strength and oxygen barrier properties, but improve its vapor barrier properties. As a result of the research it has been found, that plums were stored for the longest time without deterioration in the coating, containing wax in the amount of 20 g/100 g [8]. Scientists in [9] investigated consumer characteristics of hydroxypropyl methylcellulose-based coatings with the addition of hydrophobic components (beeswax and shellac) and food preservatives (sorbitol, Na benzoate, Na propionate and mixtures thereof) as antifungal components. Undamaged tangerines and artificially inoculated *Penicillium digitatum* or *P. italicum* were stored for 30 days at 5 °C and another 7 days at 20 °C. It has been established, that in the process of storing tangerines in a refrigerated state, coatings with antifungal additives well protect fruits from spoilage. Coatings with antioxidant and barrier properties for microorganisms based on rice starch were developed, and its effect on tomatoes, stored at room temperature, was been studied. Coconut oil and tea leaf extract were added to the rice starch-based tomato coating. The biochemical changes of fruits during storage for 20 days were studied. It has been found, that the addition of lipids and tea extract, which has antioxidant properties, in the solution to form a film significantly improves its characteristics. At the end of storage, tomatoes with a coating of starch-glycerin-lipids lost 1.78 % less weight, and tomatoes with a coating of starch-glycerin-lipids-antioxidants – by 3.53 % less than tomatoes without coating. It has been found, that coconut oil and tea extract in the coating slow down the ripening process of tomatoes during storage, and that these coatings have high barrier properties against microorganisms [10]. The simultaneous effect of antimicrobial coating, containing 0.5 % trans-cinnamic aldehyde, and γ-irradiation with doses of 0.25 and 0.5 kGy on the properties of carrots, stored for 21 days at 4 °C, was studied. It has been found, that only the combined use of both protective factors can eliminate the reproduction of *Listeria* on carrots during storage. Simultaneous use of coating and irradiation increases the sensitivity of *Listeria* to γ-irradiation [11].

An experiment was conducted to assess the effect of the wax plaque on physiological changes in fruits of sweet orange cv. “Bloody Red” at the Faculty of Horticulture, University of Dry Agriculture, Rawalpindi (Pakistan), where beeswax was used [12]. The results showed that all wax coating procedures reduce weight loss, maintain elasticity, pH, dry matter content, titrated acidity, dry matter/acid ratio, reducing sugars, non-reducing sugars, total sugars and ascorbic acid. In this study, beeswax gave better results for citrus storage than all other treatments.

Therefore, the reduction of quantitative and qualitative losses during storage of fruits and vegetables is one of the most important problems. The solution to this problem is possible with the use of advanced methods of storing vegetables. One such method is the use of paraffin coatings and growth inhibitors. However, the prospect of widespread use of protective coatings in the storage of vegetables depends largely on their quality and reliability. Pure paraffin coatings, recommended in the scientific literature, have not been widely used, as they lack the necessary adhesion and plasticity, due to which they peel off and crack. Today, the problem of reducing vegetable losses in the pre-harvest period is solved with the use of appropriate synthetic growth regulators. However, in the scientific and patent literature there is no information about the influence of growth regulators on the quality and shelf life of onion vegetables during storage.

The choice of garlic as an object of study is due to the uniqueness of this healing vegetable crop, the importance of which for human health is difficult to overestimate. Reducing the loss of garlic during storage and increasing the shelf life has economic and social effects. Improving the elements of garlic storage technology will reduce imports and sales prices.

That is why the aim of the work was to improve the elements of the technology of storage of garlic bulbs through the use of hydrophobic protective coatings, growth inhibitors. The study allows you to choose protective coatings of garlic bulbs for long-term storage and extend the duration of storage.

2. Materials and Methods

The research was conducted during 2019–2021 in an experimental field, located in the eastern part of the Left Bank Forest-Steppe of Ukraine in the Kharkiv district using drip irrigation. The influence of the type of packaging on the safety of winter garlic was studied.

Standard garlic bulbs of a winter variety Lyubasha (Ukraine) with a diameter of not less than 25 mm were stored [13]. Storage was carried out in accordance with the guidelines [14]. Prior to packaging, the garlic was cooled to storage temperature to prevent condensation. Winter garlic bulbs were stored for one day, in triplicate, weighing an average of 4 kg.

They were stored in a Polair Standard KHN-8.81 refrigerator (Russia) at a temperature of 0±0.3 °C and a relative humidity of 90–92 %, in polymer boxes № 6 according to [15].

Garlic was kept in:

1) boxes without packaging – control;

2) boxes, lined with a polyethylene film with a thickness of 40 μm according to [16], the edges of the film are tightly wrapped in the form of an envelope;

3) boxes – bulbs, treated with paraffin;

4) boxes without packaging, garlic plants, pre-treated with MAH.

Paraffin treatment was performed with a mixture of paraffin (95 %) and monoglyceride (5 %), which prevents cracking of the future protective film. Bulbs in a grid of synthetic material were placed for 2–3 s in a mixture of food paraffin and monoglyceride with a melting point of 85–88 °C.

Before harvesting garlic, when the bulbs were fully ripe, but the plant was still green, it was sprayed with 0.25 % aqueous solution of MAH at a dose of 4 kg/ha.

Observations of garlic were performed every 30 days. During storage were determined: natural weight loss and loss due to germination of bulbs. Sampling and preparation of samples for analysis was carried out in accordance with [17].

Characteristics of winter garlic of Lyubasha. Lyubasha winter garlic is large (country of origin Ukraine). Its height averages 100 to 120 cm, and some specimens, according to the description, reach 1.5 m. The leaves are rich dark green and have a light waxy coating. The length of one leaf is about 40 cm, width about 20 mm. Good yield of the variety is due to the size of the ripe head. Its weight ranges from 100 to 120 g. The color of the integumentary scales of the head is usually white, sometimes with a pink tinge, purple streaks are clearly visible on them. The color of individual teeth is closer to cream, their number may be different: from 5 to 9.

Lyubasha garlic has a lot of advantages, which include: frost resistance, resistance to drought conditions, good shelf life. Judging by the description, it does not lose its taste and benefits even after 10 months from the time of harvest. The yield of garlic from 1 ha is 35 tons (Fig. 1) [18].

Characteristics of the studied packaging materials:

Polyethylene film with the stamp "Food film" – a product, used for storage and packaging of products. The material, from which the film for food is made, has a high insulating ability. This type of packaging is low cost and easy to use. Fresh fruits and vegetables are stored only in a "breathable" polyethylene film with gas permeability – 5.43 O_2/dm^2 for 24 hours.

Food paraffin is a white or colorless soft substance, it is obtained from oil, coal or shale. Paraffin consists of a mixture of hydrocarbons, containing from twenty to forty carbon atoms. Paraffin has no taste or smell, slightly greasy to the touch, melting point 65–88 °C [19].

Fig. 1. Lyubasha garlic

3. Results

In the logistics scheme of moving vegetables from the field to the consumer, the main place is occupied by storage of products. Creating a storage regime is quite a difficult task. Its main factors are temperature, relative humidity and gas composition of the air. Combining them, choose the best storage conditions for a particular type of product, using two modes: cooling in a modified gaseous medium, while maintaining proper humidity. The temperature during storage of products can be lowered artificially or use natural conditions of cold zones. The basis of the mode of storage of products in the changed gaseous environment is the reaction of the living organism of the product to the supply of oxygen. A modification of the latter method of storage is the application of wax and paraffin on individual fruits, which provides a gaseous environment. This promotes long-term storage of vegetables and fruits. When storing products in boxes, the environment is modified by lining the middle of the box with a film (with overlapping) and loosely covering the top of the fruit. This technology preserves the turgor of vegetables and fruits and the gas composition: at the bottom of the box – 1–3 % of carbon dioxide, and at the top – less, so the impact of fungal diseases is limited.

Polyethylene films are now widely used to reduce vegetable losses during storage.

The results of studies show that the weight loss of garlic depends on the method of storage (**Table 1**).

Table 1

Structure of weight loss of garlic bulbs of the winter variety Lyubasha depending on the method of storage, %

Storage method	Losses due to dry matter	Losses due to water evaporation
Open box	69.7	30.3
Open box+polyethylene insert	54.8	45.2
Open box+bulbs, covered with paraffin	51.7	48.3

Loss of mass of vegetable products during storage depends on the type of vegetables, modes and methods of storage. It has been found, that the loss of weight of winter garlic bulbs due to dry matter ranged from 51.7 to 69.7 % depending on the method of storage. Storage of paraffin-treated bulbs in a box provided the lowest weight loss (51.7 %). During storage in boxes with polyethylene inserts, the weight loss of garlic was 4.9 % less than when stored in an open box. This is apparently due to the limited access of oxygen to the bulbs and their anaerobic respiration. It should be noted, that the use of polyethylene inserts and paraffin treatment inhibits water evaporation, and as a consequence reduces weight loss. During storage, weight loss of winter garlic bulbs occur unevenly (**Table 2**).

Table 2

Dynamics of weight loss of paraffin-treated garlic

Storage month	Natural mass losses, %	
	Paraffin-treated	Non paraffin-treated
September	0.5	0.43
October	0.65	1.35
November	0.70	2.10
December	0.77	3.30
January	1.10	3.90
February	1.50	4.20
Totally	4.52	15.28

An important biological feature of garlic is the ability to go to a state of shallow dormancy. There is a link between dormancy and resistance to microbiological damage. The earlier the growth and development of the buds begins, the faster the outflow of active substances to the meristem of growth cones. It has been found, that the natural weight loss of bulbs depends on their paraffin treatment, as well as the duration of storage. By the beginning of the bulbs come out of dormancy, the weight loss grows slowly: from 0.43–0.5 % in September to 1.1–3.9 % in January. The largest weight loss is 1.5–4.2 % in February, after six months of storage. Garlic teeth lose their marketability and resistance to microbiological damage. It has been found, that treatment of bulbs with paraffin reduces weight loss by 10.76 % (**Table 2**).

The dependence of the weight loss of winter garlic bulbs on the peculiarities of the storage method has been established (**Table 3**).

Table 3

Correlation dependence of weight loss of winter garlic bulbs on the method of storage

Storage method	Linear dependence	Determination coefficient
Open box	Y=0.802x–0.582	R^2=0.985
Open box+polyethylene insert	Y=0.636x–0.466	R^2=0.991
Open box+bulbs, covered with paraffin	Y=0.183**x**+0.228	R^2=0 873

After four months of storage, the bulbs come out of dormancy and begin to germinate. The number of germinated bulbs after six months of storage is 0.2–6.2 %. Treatment of plants with MAH helps to reduce losses due to germination of bulbs, damage by microorganisms, drying compared with the control option and storage in boxes with polyethylene inserts. The yield of marketable products is 85.3 %, which exceeds the corresponding options by 20.0 and 7.0 %. The highest yield of marketable bulbs 91.8 % is provided by their treatment with paraffin (Table 4).

Table 4

Preservation of garlic depending on the method of storage and treatment with growth-inhibiting substances, %

Storage method	Natural mass losses, %	Losses due to diseases, %	Germinated bulbs, %	Dry bulbs, %	Yield of marketable products, %
Open box	15.3	2.3	10.9	6.2	65.3
Open box+polyethylene insert	8.7	2.5	6.2	4.3	78.3
Open box+bulbs, covered with paraffin	4.5	1.7	1.4	1.2	91.8
Plants, treated with MAH	9.2	1.2	0.2	4.1	85.3
HIP_{05}	0.77	0.94	0.24	1.25	1.53
Factor influence intensity	0.98	0.54	0.98	0.92	0.98
Data variation	43.6	68.7	98.5	50.5	12.8

The analysis of variance showed that the method of storage affects 98 % of the safety of garlic. 54 % – of development of diseases. Treatment with MAH affected the germination of bulbs by 98 %.

Studies of the impact of storage on the safety of garlic are not cost-effective and do not require additional equipment.

Further research can be carried out using fungicides and antiseptics in a mixture of paraffin and glycerin. Such treatment can be effective against damage to bulbs by microorganisms.

4. Conclusions

It has been found, that the loss of weight of garlic bulbs during storage depends on the method of storage and type of treatment of garlic plants. Weight loss during storage in boxes with polyethylene inserts is reduced by 2 times, bulbs, treated with paraffin, – by 3.4 times.

Treatment of plants with MAH helps to reduce weight loss by 1.7 times. After 6 months of storage, the loss due to dry matter ranged from 51.7 to 69.7 % of weight loss.

Treatment of plants with MAH helps to reduce losses due to germination of bulbs, damage by microorganisms, drying compared to the control version and storage in boxes with polyethylene inserts. The highest yield of commercial bulbs 91.8 % is provided by their treatment with paraffin. The analysis of variance has found that the method of storage affects 98 % of garlic safety, the development of diseases – by 54 %. Treatment with MAH affected the germination of bulbs by 98 %.

Based on the obtained results, the correlation analysis was performed and the linear dependence of the weight loss of winter garlic bulbs depending on the peculiarities of the storage method was established.

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