EFFECTIVENESS OF PRODUCTS THAT INHIBIT ETHYLENE SYNTHESIS IN THE APPLE FRUITS DURING THE POST HARVEST PERIOD

EFICACITATEA PRODUSELOR CE INHIBĂ SINTEZA ETILENEI ÎN FRUCTELE DE MĂR ÎN PERIOADA DE POST RECOLTARE

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Abstract.
To evaluate the effectiveness of treatment with the ethylene biosynthesis inhibitor 1-MCP during storage of the Gala Dark Baron variety, the following experimental scheme was developed: 1. Normal atmosphere (C), no treatment; 2. Fitomag, 0.44 g/m^3; 3. Grand Fresh, 60 g/m^3; 4. Grand Fresh, 68 g/m^3. The fruits of the control and treated variants were placed in room with a normal atmosphere (CO_2 - 0.03%; O_2 - 21%). Storage temperature 0...+1^{0}C and relative humidity 92-95%. The storage period was 150 days. Treating fruit with products whose active substance is 1-MCP before storage increases pulp firmness, DA-Meter index values, standard fruit yield, decreases ethylene emission, natural loss, fungal disease, and extends the "shelf life" of apples compared to the control variant.
Key words: 1-MCP, ethylene, firmness, ripening, DA-Meter

Rezumat.
Pentru a determina eficacitatea tratamentului cu inhibitorul de biosinteză a etilenei 1-MCP în perioada de depozitare la soiului Gala Dark Baron, a fost elaborată următoarea schemă experimentală: 1. Atmosferă normală (C), fără tratament; 2. Fitomag, 0,44 g/m^3; 3. Grand Fresh, 60 g/m^3; 4. Grand Fresh, 68 g/m3. Fructele din variantele martor şi cele tratate au fost plasate în camere cu atmosferă normală (CO_2 - 0,03%; O_2 - 21%). Temperatura de depozitare a fost de 0...+1^{0}C, iar umiditatea relativă de 92-95%. Perioada de depozitare a fost de 150 de zile. Tratarea fructelor cu produse a căror substanţa activa este 1-MCP înainte de depozitare creste fermitatea pulpei, valorile indicelui DA-Meter, randamentul fructelor standard, scade pondera de etilenă emanată, pierderea naturala, afecțiunea de boli fungice, prelungește perioada de „raft" a merelor în comparație cu varianta martor.
Cuvinte cheie: 1-MCP, etilenă, fermitate, maturitate, DA-Meter

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INTRODUCTION

Apple culture is a species that is cultivated on the territory of our country on large areas [Babuc *et al.,* 2010; Babuc *et al.,* 2015; Peşteanu and Calestru, 2025], influencing particularly important in the lives of rural residents, where it constitutes a source of livelihood and income [Babuc *et al.*, 2010; Babuc *et al.*, 2013; Balan *et al.,* 2025].

Stable and quality harvests must be accompanied by the use of progressive methods of fruit preservation in the post-harvest period. This allows consumers to permanently use fresh products, rich in mineral elements and beneficial for the human body [Babuc *et al.,* 2013; Bujoreanu and Chirtoca, 2013].

At present, post-harvest storage technologies applied in the Republic of Moldova do not ensure the maintenance of high-quality fruits and their resistance to various disorders caused by fungal diseases [Babuc *et al.,* 2013; Bujoreanu and Chirtoca, 2013; Nicuță, 2023].

The disadvantages described above can be eliminated by implementing new methods of storing apples. Among these innovations is the use of growth regulators that inhibit the emission of ethylene from climacteric fruits, whose active substance is 1-MCP (1-methylcyclopropene) [Babuc *et al.,* 2013; Bujoreanu and Chirtoca, 2013; Nicuță, 2023; Гудковский *et al.,* 2013].

MATERIAL AND METHOD

The Gala Dark Baron apples were grown on trees grafted on M9 rootstock, with a vertical crown shape and a planting distance of 3.5 x 0.8 m.

To determine the effectiveness of treatment with ethylene biosynthesis inhibitors on the storage capacity of apples during the post-harvest period, the following experimental scheme was developed: 1. Normal atmosphere (NA), control; 2. Fitomag, 0.44 g/м^3; 3. Grand Fresh, 60 g/м^3; 4. Grand Fresh, 68 g/м^3. In variants 2-4, the fruits were stored in normal atmosphere and treated with growth regulators whose active substance is 1-MCP.

After harvesting, the apples were transported to the refrigerator, where they were subjected to cooling, gradually lowering the temperature from +20.5°C to +0.4°C. The cooled fruits were treated with growth regulators with the ability to inhibit ethylene biosynthesis (Fitomag, Grand Fresh) according to the methodology developed at the Miciurinsk Institute of Fruit Growing [Гудковский *et al.,* 2013].

The fruits were kept closed in a gaseous environment for 24 hours, followed by ventilation for a period of 15 minutes. The fruits of the control variants and those treated with an ethylene biosynthesis inhibitor were placed for storage in rooms with a normal atmosphere - NA (CO_2 - 0.03%; O_2 - 21%).

The storage temperature during the experiment for the Gala Dark Baron variety was maintained at the level of 0...+10C and humidity 92-95%. Control over the temperature regime and composition of the atmosphere - constant, automatic. The storage period was 150 days.

Data were processed using the ANOVA test and STATGRAPHICS Centurion 18. The differences were considered statistically significant if the probability was greater than 95% (p-value < 0.05).

RESULTS AND DISCUSSIONS

The firmness of the pulp of apple fruits of the Gala Dark Baron variety at the time of harvesting was 9.5 kg/cm^2, which is considered optimal for harvesting fruits and their placement for long-term storage and preservation.

The firmness of fruits changes under the influence of growth regulators intended to inhibit ethylene biosynthesis (Fitomag, Grand Fresh). If, in the control variant, the firmness of apples during the storage period decreased from 9.5 to 6.2 kg/cm^2, then in the variants treated with the ethylene biosynthesis inhibitor, the corresponding indicator was 7.2 kg/cm^2, that is, there was an increase in the firmness of the pulp by 1.0 kg/cm^2 (Table 1).

Table 1

The effect of treatment with ethylene biosynthesis inhibitors on changes in fruit pulp firmness dynamics during the post-harvest period, (kg/cm^2)

Variants	Determination period				
	02.10.21	02.11.21	02.12.21	02.01.22	02.02.22
Normal atmosphere (c)	8.9	8.4	7.7	7.0	6.2
Fitomag, 0.44 g/м^3	9.1	8.6	8.1	7.5	6.9
Grand Fresh, 60 mg/м^3	9.0	8.5	8.0	7.4	6.8
Grand Fresh, 68 mg/м^3	9.1	8.7	8.1	7.7	7.2
LSD 0.05	0.39	0.35	0.34	0.32	0.31

After five months of fruit storage, the firmness of apples in the control variant decreased by 34.8%, and in the variant treated with the Fitomag product, 0.44 g/m^3 by 27.4%. In the case of the variant treated with the growth regulator Grand Fresh, 60 mg/m^3, the index under study decreased by 28.4%, and in the Grand Fresh variant, 68 mg/m^3 by 24.2%.

During the storage period of apples, the maximum intensity of ethylene emanation was recorded in the control variant 3.4-13.7 ppm. Post-harvest treatment of fruits with the Fitomag and Grand Fresh products reduced the intensity of ethylene emanation. In the Fitomag variant at a dose of 0.44 g/m^3, the intensity of ethylene emanation from fruits during storage was 1.9-2.7 ppm (Table 2).

Table 2

The influence of growth regulators on the dynamics of the intensity of ethylene release (ppm) by apple fruits during storage, ppm

Variants	Determination period				
	02.10.21	02.11.21	02.12.21	02.01.22	02.02.22
Normal atmosphere (c)	3.4	5.0	7.2	9.6	13.7
Fitomag, 0.44 g/м^3	1.9	2.0	2.1	2.3	2,.
Grand Fresh, 60 mg/м^3	1.9	2.0	2.2	2.3	2,.
Grand Fresh, 68 mg/м^3	1.8	1.9	1.9	1.8	2,.
LDS 0.05	0.09	0.09	0.10	0.10	0.13

In the variant treated with the Grand Fresh product, 60 mg/m^3, the studied index was approximately at the same level as the Fitomag variant, 0.44 g/m^3. In the

variant treated with Grand Fresh, 68 mg/m^3, the studied indicator decreased to the minimum values, ranging from 1.8 to 2.0 ppm.

Treatment of apple fruits with an ethylene biosynthesis inhibitor (Fitomag, Grand Fresh) contributed to preserving the firmness of the fruits and decreasing the intensity of ethylene release, both during storage and during the "shelf life" period.

After 5 months of storage + the "shelf life" period, the firmness of the fruits ranged from 5.2 to 7.0 kg/cm^2 according to the experimental variants. The minimum firmness of the fruits according to the studied variants was obtained in the control variant - 5.2 kg/cm^2. Fruit treatment with Fitomag, 0.44 g/m^3 and Grand Fresh, 60 mg/m^3 products influenced apple firmness (6.4 kg/cm^2), but not to the same extent as in the Grand Fresh, 68 mg/m^3 (7.0 kg/cm^2) variant (Table 3).

Table 3

The effect of treatment with ethylene biosynthesis inhibitors on fruit firmness and ethylene release intensity after 5 months of storage and during the "shelf life" period

Variants	Fruit firmness (kg/cm^2)		Ethylene emission intensity (ppm)	
	When storing	+7 days t+18–22^{0}C	When storing	+7 days t+18–22^{0}C
Normal atmosphere (c)	6.2	5.2	13.7	23.4
Fitomag, 0.44 g/м^3	6.9	6.4	2.7	3.7
Grand Fresh, 60 mg/м^3	6.8	6.4	2.7	3.8
Grand Fresh, 68 mg/м^3	7.2	7.0	2.0	2.4

The maximum intensity of ethylene emission was recorded in the control variant - 23.4 ppm, or an increase of 70.8% compared to the period of removing the fruits from storage. In the variant treated with the Fitomag product, 0.44 g/m^3, the studied index was 3.7 ppm, or an increase of 37.0%. In the case of the Grand Fresh variant, 60 mg/m^3, the amount of ethylene released from the fruits was approximately the same as the Fitomag variant, 0.44 g/m^3, registering 3.8 ppm. In the variant treated with Grand Fresh, 68 mg/m^3, the amount of ethylene released during the "shelf life" period of the apples was 2.4 ppm.

The DA-Meter index determines the ripening of the fruits based on the degradation of the chlorophyll content, which decreases with the intensification of the process of ethylene emission from the apple. The apple ripening index within a month from the moment of harvesting in the studied variants ranged from 0.44 to 0.54. So, the ripening index of apples changes under the influence of the growth regulators Fitomag and Grand Fresh, which are designed to inhibit ethylene biosynthesis (Table 4).

Table 4

The influence of growth regulators on the dynamics of ripening of apple fruits of the Gala Dark Baron variety during storage based on the DA-Meter index

Variants	Determination period				
	02.10.21	02.11.21	02.12.21	02.01.22	02.02.22

Normal atmosphere (c)	0.44	0.42	0.40	0.36	0.32
Fitomag, 0.44 g/м^3	0.49	0.48	0.45	0.43	0.40
Grand Fresh, 60 mg/м^3	0.50	0.48	0.45	0.44	0.40
Grand Fresh, 68 mg/м^3	0.54	0.53	0.51	0.49	0.47

If in the case of the control variant the apple ripening index was 0.44, then in the variants treated with Fitomag and Grand Fresh growth regulators, the corresponding indicator was 0.49-0.54.

After 5 months of apple storage, a high intensity of the degree of fruit ripening was observed in the control variant - 0.32, and in the variant treated with the growth regulator for inhibiting ethylene biosynthesis Grand Fresh at a dose of 68 mg/m^3, this indicator was 0.47, or was 46.8% higher compared to the previous variant.

Post-harvest treatment of fruits with the studied products after 5 months of storage increased the yield of standard fruits (Table 5). The optimal natural loss for apples during long-term storage in refrigerators with artificial cooling is 3-4%. The highest natural loss was observed after 5 months of storage in the control variant - 3.8%. Treatment of fruits with 1-MCP-based preparations (Fitomag and Grand Fresh) reduced the studied parameter, constituting 1.7-2.6%. The difference between the variants treated with the ethylene emanation inhibitor Grand Fresh, constituted 0.9%.

Table 5

The effect of treatment with ethylene biosynthesis inhibitors on standard fruit yield, natural loss and fungal infection damage after 5 months of storage, %

Variants	After 5 months of storage			+7 days T+18–22^{0}C
	Standard fruits, %	Natural losses, %	Botrytis cinerea,%	Botrytis cinerea,%
Normal atmosphere (c)	95.2	3.8	4.8	9.2
Fitomag, 0.44 g/м^3	98.8	2.4	1.2	1.6
Grand Fresh, 60 mg/м^3	98.4	2.6	1.4	1.7
Grand Fresh, 68 mg/м^3	100.0	1.7	-	-
LDS 0.05	1.1	0.21	-	-

The main losses during fruit storage are those recorded from fungal infections (fruit rot, gray mold, etc.). The highest share of fruit affected by fungal rot after 5 months of storage and during the "shelf life" period was noted in the control variant, where these values constituted 4.8 and 9.2%, respectively.

Fig. 1. Appearance of Gala Dark Baron apples after 5 months of storage in various variants treated with the growth regulator that inhibits ethylene synthesis

The share of fruits damaged by Botrytis cinerea during storage in the Fitomag variant at a dose of 0.44 g/m3 was 1.2%, and when using the tested growth regulator Grand Fresh, at a dose of 60 mg/m^3, it was 1.4%. Further maintenance of these apples for 7 days at room temperature (+18–22^{0}C) led to a slight increase in the proportion of fruits affected by fungal diseases, but not to the same extent as in the control variant.

CONCLUSIONS

Treating fruits with products based on the ethylene synthesis inhibitor 1-MCP before storage influenced the firmness of apple pulp, the share of ethylene emitted by the fruits and increased the DA-Meter index values after 5 months of storage, compared to the normal atmosphere variant, control.

Treating fruits with products based on the ethylene synthesis inhibitor 1-MCP before storage in a normal atmosphere regime increased the yield of standard fruits, decreased the degree of natural perishability, Botrytis cinerea diseases and extended the "shelf life" period of apples compared to the control variant.

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