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INTENSITY OF THE APPLES RESPIRATION PROCESS DEPENDING ON THE STORAGE TECHNOLOGY APPLIED

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INTRODUCTION

Apple accounts for about 60-70% of the volume of fruit produced in Moldova and ranks first in terms of storing fruit in cold rooms.

In our country and in the world, more and more attention is paid to the quality of food products every year. Storage of fruit in optimal conditions for a long period of time and with the least loss of production can be achieved taking into account a number of factors, which can influence their quality and resistance to various diseases during storage.

Metabolic activity in fresh fruits continues for a short period after harvest. The energy required to sustain this activity comes from the respiration process (Mannapperuma J. et al., 1991).

The storage life of a commodity is influenced by its respiratory activity. (Halachmy and Mannheim, 1991).

The amount of CO2 released in the respiration process is an indicator for assessing the rate of biodegradation of reserve substances (Burzo et al., 1999). In the process of respiration, sugars are mainly oxidized, and when the carbohydrate substrate is depleted, the respiration continues to oxidize other substances (organic acids, protein substances, ascorbic acid, etc.) (Lazăr, 2006). So, in order to preserve the quality and nutritional value of fruits, it is necessary to slow down their ripening processes to the maximum, first of all the respiration which also depends on the properties of the cultivar and the method of storage applied.

At this time, storage technologies such as normal atmosphere (NA), modified (MA) and controlled atmosphere (CA) are used. However, the existing storage technologies have their advantages and disadvantages, differ in the costs of their implementation and do not always provide guaranteed protection of fruits from damage by many physiological and fungal diseases, as well as preservation of their original quality (freshness, firmness, nutritional value) at the stages of storage, transportation and implementation. For these reasons, manufacturers suffer huge losses, and consumers are not always satisfied with the quality of the products.

Storage in normal atmosphere is the most common and less expensive way in the Republic of Moldova. The disadvantages of NA include: a short storage period (2-4 months), rapid ripening of fruits, damage by physiological and microbiological diseases, loss of quality (Гудковский et al., 2010; Nicuță, 2018).

Currently, the most efficient technology for long-term storage of fruits and vegetables is the controlled atmosphere storage technology (high CO_2 and low O_2) (Урнев, 2018; Zanella A. et al., 2008). However, storage in CA not in all cultivars provides effective protection against scald and other physiological diseases (Гудковский et al., 2016). At the same time, it is an expensive storage method. Therefore, in many horticultural farms in the Republic of Moldova, to slow down the rate of post-harvest ripening and effectively protect against physiological diseases, they began to use chemical synthesis substances.

One of the promising methods is to treat the fruit after harvest with the inhibitor of ethylene bio-synthesis ‘Fitomag’ (active substance - 1-methyl-cyclopropene (1-MCP)). The preparation has been synthesized by scientists from the Russian Federation and is harmless to human health and the environment. It is registered and authorized for practical use in several countries, including in the Republic of Moldova. This technology does not require significant costs (requires less sophisticated equipment, reduced electricity consumption, simplicity of application, etc.) compared to the method of storage fruit in a controlled atmosphere, by ensuring the same quality of fruit of many apple varieties. It was found that the preparation in question does not allow ethylene to intensify metabolic processes in fruit during storage, reduces the intensity of the respiration process, and for most apple cultivars the storage life in refrigerators with normal atmosphere can be extended by 2-3 months, the quality of the fruit being maintained at a high level (Гудковский et al., 2009; Гудковский et al., 2013; Goudkovski et al., 2012). This can serve as an advantage for many fruit producers in the Republic of Moldova who cannot afford financial investments in the construction of refrigerators equipped with modern equipment.

Based on the above, the purpose of our research was to assess the degree of influence of the preparation ‘Fitomag’ during the storage period on the respiration process of the fruits of late apple cultivars, grown in the pedoclimatic conditions of the Republic of Moldova.

MATERIAL AND METHODS

Apples ‘Idared’, ‘Golden Delicious’, ‘Florina’, and ‘Reinette ‘Simirenko’ were collected in SRL Lefcons -Agro, Floreni district, Ungheni region, Republic of Moldova. The apples were harvested in the stage of maturity. Harvested fruits were transported to the Institute of Genetics, Physiology and Plant Protection, Chisinau, Republic of Moldova within 3 h.

The next day after harvest, fruits were randomly divided into 2 groups of 12 wooden crates with 100 fruits in each crate (300 fruits per cultivar). The apples in the first group were assigned the destination as control fruits (untreated). On the same day, the second group of fruits were then treated with 1-MCP (preparative form ‘Fitomag’, 0.44 $g{\cdot}m^{-3}$, „Fito-Mag”, Moscow, Russian Federation) in an airtight container for 24 hours, with subsequent storage under the same conditions as the control. For the post-harvest treatment of apples, a dose of 0.22 - 0.44 g m^{-3} of ‘Fitomag’ registered in the Republic of Moldova.

The fruits were stored for 150 days in experimental refrigeration rooms (KHT-1M) according to the scheme:

1. **Normal atmosphere (NA) - control (non-treated fruits)** (O_2 - 21 %, CO_2 - 0,03%). Apples were stored at 1 °C and relative air humidity of 85–90%;

2.**‘Fitomag’ + NA** - (O_2 - 21 %, CO_2 - 0,03%). Apples were stored at 1°C and relative air humidity of 85–90%.

Post-harvest treatment with ‘Fitomag’ and laboratory investigations were performed at the Institute of Genetics, Physiology and Plant Protection, Chisinau, Republic of Moldova.

During the storage period, several physiological and physico-chemical parameters were investtigated. Respiration rate as carbon dioxide production was estimated by the Починок/Pochinok method by absorption in 0,05 N $Ba(OH)_2{\cdot}8H_2O$ and titration with 0,05 N oxalic acid ($C_2H_2O_4$), using phenolphthalein (Починок, 1976).

The principle of the working method

To perform this experiment, 1 kg of apples (treated and untreated) of each cultivar was selected. Apples were placed in desiccators on perforated inserts and closed tightly with lids. All desiccators, including one without fruit (control) were connected to a vacuum pump and air was blown for 10 minutes simultaneously through all desiccators. After the desiccators were disconnected, the tips of semi-automatic pipettes were inserted into a rubber tube of a long glass tube in the desiccator, and 100 ml of a Ba $(OH)_2$ solution was poured in. The rubber tubes were closed with clamps, and the samples were left for 1 hour. Then, using pipettes, the volume of the solution was taken from each desiccator and poured into a dry flask with a stopper. Each sample was titrated with an oxalic acid solution in the presence of phenolphthalein.

CO_2 measurements were carried out every 5-7 days, using the same fruits throughout the storage period.

Respiratory intensity was calculated according to formula:

$$\frac{100 \cdot 22 \cdot A \cdot K\,(a-b)}{1{,}98 \cdot v \cdot n \cdot t}$$

where: 100 - recalculation per 100 g of material; 22 - g-equiv of carbon dioxide in reaction with $Ba(OH)_2$; A - is the volume of 0.05 N solution of $Ba(OH)_2$ taken into the desiccator at the beginning of the experiment (in mL); K - oxalic acid solution normality; a-the volume of a titrated solution of oxalic acid con-sumed during the titration of $Ba(OH)_2$ in a control desiccator (in mL); b - volume of titrated solution of oxalic acid consumed during the titration of $Ba(OH)_2$ in the experiment (in mL); 1,98 - CO_2 density under normal conditions (in g / L); v - volume of Ba(OH) 2 solution taken for titration after the experiment (in mL); n - weight of the researched material (in g); t - duration of experience (in hours). Results were expressed in milligrams of CO_2 produced per kilo-gram of fruit in 1 h (mg CO_2/kg·hr).

The processing of experimental data was carried out using a table editor Microsoft Excel.

RESULTS AND DISCUSSION

The intensity of the respiration process varies under the action of exogenous factors (temperature and composition of the atmosphere) or endogenous (fruit size, health, respiratory substrate, the presence of ethylene, etc.) (Lazar, 2006). The optimum storage temperature may vary by species and cultivar. Temperature variations have negative effects on maintaining the quality of agricultural products (Burzo et al., 1999). Schulz H. (1984) mentions that at any storage temperature apples reach a respiratory peak (climacteric maximum), but at low temperatures it is less prominent. At the same time, with the increase of the temperature, the period of the appearance of the climacteric maximum is shortened. However, there are significant differences between certain species and cultivars of fruit in this regard. For example, in the case of pears fruits with increasing temperature, the climacteric period appears earlier compared to apple fruits. In practice, this means that for pears the maximum storage period can be ensured by maintaining a temperature in the cold room within the limits of +1 to -1°C, and for apples, on the contrary, within the limits of +4 ...5°C and up to -1°C, depending on their predisposition to physiological diseases in conditions of low temperatures (Феткенхойер, 1984). The second important factor that influences the intensity of the respiration process during the post-harvest period is the composition of the atmosphere, which is due to the high CO_2 content and low O_2 content. This is based on storage the fruit in a controlled atmosphere.

Also, the respiration rate of fruits is closely related to the permeability of tissues: the freer access to oxygen, the more intense the respiration of fruits (Метлицкий, 1970**).**

According to the way of breathing during the ripening period, the fruits are divided into two groups - climacteric and non-climacteric. The intensity of respiration of climacteric fruits (apples, pears, apricots, etc.) increases to the climacteric maximum (respiratory peak), after which it decreases. The period in which the intensity of respiration increases is called climacteric and is associated with fruit ripening, the climacteric maximum - with the state of maturation, and the period of decreasing the intensity of the respiration process (postclimacteric) - with fruit sensecence. Species that show a similar dynamics of the intensity of the respiration process have been called non-climacteric (cherries, grapes, oranges, etc.) (Burzo et al., 1999; Bujoreanu, 2010). The climacteric period is characterized by an intensification of the respiration process, especially by the elimination of CO_2 and the lower use of O_2. At this stage, the synthesis of new proteins, including enzymatic ones, takes place, which performs the decarboxylation of malic acid. In the postclimacteric period, processes diametrically opposed to those of previous periods take place, because during it the destruction processes prevail. The disintegration of mitochondria and other cellular structures begins, as well as the separation of oxidation and phosphorrylation processes, as a result of which the fruits lack the energy needed to maintain the cellular structures and vitality of the body (Bujoreanu, 2010). As a result, the resistance of fruits to fungal diseases and physiological disorders decreases, weight loss and consumption of plastic substances (sugars, organic acids, vitamin C, etc.) increase, processes that essentially reduce the taste qualities of fruits.

Apple is a climacteric fruit presenting a typical peak in the respiration rate that precedes or is parallel to an autocatalytic rise in ethylene production (Lurie S., 1998a; Lurie S., 1998b). The magnitude and timing of the respiratory peak varies among species. Sugars and organic acids, the main respiratory substrates, are sequestered in the vacuole and presumably released in a controlled way into the cytosol to become available for respiration (Sigal-Escalada V., 2006).

In the dynamics of storage the fruits of the Golden Delicious', Florina, Idared and Reinette Simirenko cultivars, a different degree of respiration intensity was registered, which can be associated also with the characteristic features of these cultivars. As a result of the storage of apple fruits of the above mentioned cultivars, it was obtained that the storage method had a significant influence on the respiration process, the intensity of which depended largely on the applied storage technology and the biological peculiarities of the cultivar. From the presented results it results that the highest intensity of the respiration process was registered in the control fruits (Figure. 1, Figure 2, Figure 3, Figure 4). On the other hand, the intensity of the respiration process in the fruits treated with Fitomag was significantly slowed down, the climacteric period intervening late, which made possible the appearance of the respiratory peak for a later period, compared to the fruits in the control variant (Figures 1, 2, 3 and 4).

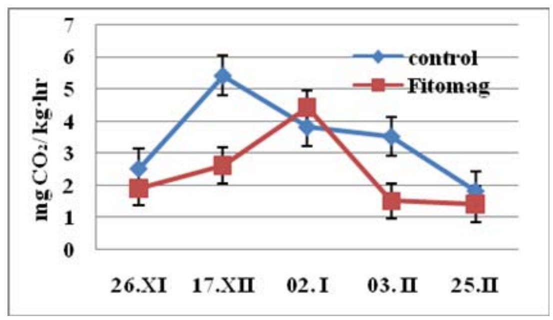

Fig. 1. Respiration of ‘Golden Delicious’ apple

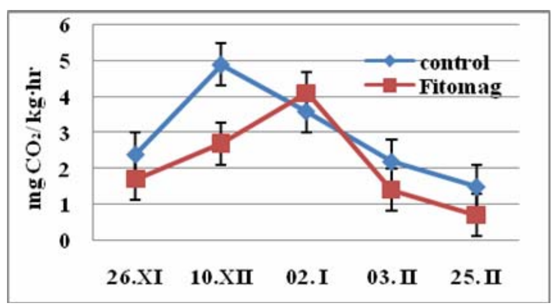

Fig. 2. Respiration of ‘Florina’ apple

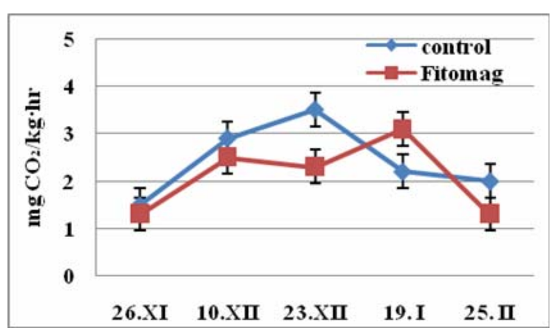

Fig. 3. Respiration of ‘Idared’ apple

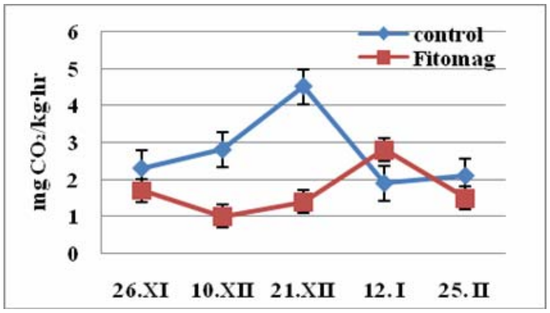

Fig. 4. Respiration of 'Reinette 'Simirenko' apples

The data obtained show that in the dynamics of storage, in the control fruits, the highest degree of respiration intensity was recorded in the cultivar 'Golden Delicious' - 1,80-5,40 $mgCO_2/kg·hr$ (Figure1), and the highest reduced to the 'Idared' cultivar - 1,10-3,50 $mgCO_2/kg·hr$ (Figure 3). In the case of treated fruits, this legality was partially valid for the given cultivars, the highest respiration rate being recorded for the 'Golden Delicious' cultivar - 1,20 - 4,40 $mgCO_2/kg·hr$, but lower in the 'Reinette Simirenko' cultivar - 0,6 - 2,80 $mgCO_2/kg·hr$ (Figure 4). The 'Idared' apple cultivar, as in the control variant, is marked by low respiration parameters - 1,10 - 3,10 $mgCO_2/kg·hr$, and the 'Florina' cultivar showed a level of 0,7 - 4,10 $mgCO_2/kg·hr$ (Figure 2). In this context, it should be noted that different respiration activity in fruits of different apple cultivars in a certain degree is associated with the structure of their integumenttary tissues, as well as with the presence of pores and lentils, through which diffusion of O_2 and CO_2 gases occurs (Метлицкий et al., 1977). The results obtained from the research of the 'Fitomag' preparation allow us to talk about the fact that the post-harvest treatment of fruits with this pre-paration favors a decrease in respiration intensity, less CO_2 is released, which means that the consumption of plastics substances (sugars, organic acids , vitamin C etc.) used in the maintenance of this process was lower. This indicates that the post-harvest treatment of the fruit with the preparation 'Fitomag' has a positive influence on the quality of the fruit, slowing down the maturation-senescence processes, thus preserving the nutritional and gustatory value of the apples.

CONCLUSIONS

1. The storage method had a significant influence on the respiration process, the intensity of which largely depended on the storage technology applied and the biological characteristics of the cultivar.
2. The intensity of the respiration process in the fruits treated with 'Fitomag' was significantly slowed during the storage period, which made possible the appearance of the respiratory peak for a later period, compared to the fruits of the control variant. This indicates that the metabolic processes in the treated fruit went slower, which was a beneficial effect on the quality of the fruit. At the time of release from storage, the fruits treated with the 'Fitomag' preparation were highlighted by freshness, high structo-textural firmness and low degree of damage with fungal diseases and physiological disorders.

ABSTRACT

This article presents data on the influence of applied storage technology on the intensity of the respiration process of apples. The process of respiration is an indicator of the intensity of ripening and biodegradation of plastics substances in fruits. The intensity of the respiration process in the fruits treated with the 'Fitomag' preparation was significantly slowed down during the storage period, which made it possible to trigger the respiratory peak for a later period compared to the fruits in the control variant. At the time of discharge from storage, the fruits treated with the 'Fitomag' preparation were highlighted by freshness, high structotextural firmness and low degree of damage with fungal diseases and physiological disorders.

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REFERENCES

1. BURZO I., TOMA S., DOBRESCU A., CRĂCIUN C., VOICAN V., DELIAN E., 1999 – Fiziologia plantelor de cultură, vol.1., Chişinău: Ştiinta. 464 p. [Physiology of cultivated plants, vol.1., Chisinau: Science];
2. BUJOREANU N., 2010 - Formarea directionată a fructelor pentru păstrare îndelungată. Chişinau: Magna Priceps SRL, 256 p. [Directed fruit formation for long storage. Chişinau: Magna Priceps SRL];
3. GOUDKOVSKY, V.A., KOZHINA, L.V., BALAKIREV, A.Y., NAZAROV, Y.B., 2012 – Efficiency of apple fruit storage in air, controlled and modified atmospheres. Proceedings of the 2nd International Scientific Conference „Sustainable Fruit Growing: From Plant to Product". Rīga-Dobele, Latvia, 22-24 August 2012, pp.34-38;
4. HALACHMY I.B., MANNHEIM C.H., 1991 – Modified Atmosphere Packaging of Fresh Mush-rooms. Packaging Technology and Science, 4(5), pp. 279-286;
5. LURIE S., 1998a - Postharvest heat treatments. Postharvest Biology and Technology, 14, pp. 257-269;
6. LURIE S., 1998b - Postharvest heat treatments

of horticultural crops. Hort. Rev., 22, pp. 91-121;
7. LAZĂR V., 2006 - Tehnologia păstrării şi industrializării produselor horticole. Cluj-Napoca: Editura Academic Pres, 275 p. [Technology for storage and industrialization of horticultural products.];
8. MANNAPPERUMA J.D., SINGH R.P., MONTERO M.E., 1991 - Simultaneous Gas Diffusion and Chemical Reaction in Foods Stored in Modified Atmospheres. Journal of Food Engineering, 14(3), pp. 167-183;
9. NICUȚĂ A., 2018 - Influența preparatului „Fitomag" asupra modificării valorilor unor indici biochimici la fructele de măr pe parcursul perioadei de păstrare îndelungată. Studia Universitatis, Seria Ştiințe Reale şi ale Naturii, nr. 1(111), Universitatea de Stat din Chişinău, pp. 82-85 [The influence of the preparation "Fitomag" on the change of the values of some biochemical indices in apple fruits during the long storage period. Studia Universitatis, Real and Natural Sciences Series, no. 1(111), Chisinau State University];
10. SIGAL-ESCALADA V., 2006 - "Interactions of AVG, MCP and heat treatment on apple fruit ripening and quality after harvest and cold storage". University of Kentucky, Doctoral Dissertations. 448.
11. ZANELLA A., GAZANELLY P., ROSSI O., 2008 - Dynamic controlled atmosphere storage by means of chlorophyll fluorescence response for firmness retention in apples. Proc. IC on Ripening Regulation and Postharvest fruit quality. Acta Hort. 796, pp.77-82;
12. ГУДКОВСКИЙ В.А., КОЖИНА Л.В., БАЛАКИРЕВ А.Е., НАЗАРОВ Ю.Б., 2009 - Эффективность модифицированной атмосферы и ингибитора биосинтеза этилена для хранения плодов, ягод и овощей//Вестник Мичуринского государственного аграрного университета, № 1, с. 53-64 [GUDKOVSKY V.A., KOZHINA L.V., BALAKIREV A.E., NAZAROV Y. B., 2009 - Efficiency of a modified atmosphere and an inhibitor of ethylene biosynthesis for storage of fruits, berries and vegetables // Bulletin of Michurinsky State Agrarian University, No. 1 , pp. 53-64];
13. ГУДКОВСКИЙ В. А., КЛАДЬ А. А., ПЕРЕПЕЛИЦА А. П., ОЛЕФИР Е. А., 2010 - Эффективность технологии хранения яблок сорта Голден Делишес в модифицированной атмосфере//Вестник Мичуринского государственного аграрного университета, № 2, с. 140-142 [Efficiency of storage technology for Golden Delicious apples in a modified atmosphere // Bulletin of Michurinsky State Agrarian Uni-versity, No. 2, pp.140-142];
14. ГУДКОВСКИЙ В.А., КОЖИНА Л.В., БАЛАКИРЕВ А.Е., НАЗАРОВ Ю.Б., 2013 – Основные итоги исследований по совершенствованию технологий хранения плодоовощной продукции//Хранение и переработка сельхозсырья, № 9, с. 34-39 [The main results of research on improving storage technologies for fruit and vegetable products // Storage and processing of agricultural raw materials, no. 9, pp. 34-39];
15. ГУДКОВСКИЙ В.А., КОЖИНА Л.В.,УРНЕВ В. Л., 2016 - Современные технологии хранения плодов сорта Синап Орловский//Вестник Мичуринского государственного университета: научно-производственный журнал, №3, с. 83-91 [Modern technologies for storing fruits of the Sinap Orlovsky cultivar // Bulletin of Michurinsky State University: scientific and production journal, No. 3, pp. 83-91];
16. МЕТЛИЦКИЙ, Л. В., 1970 - Биохимия плодов и овощей. Москва: Экономика, 271 с. [METLITSKY, L. V., 1970 - Biochemistry of fruits and vegetables. Moscow: Econom., 271 p.];
17. ПОЧИНОК Х. Н., 1976 - Методы биохимического анализа растений. Киев. « Наукова думка», 334 с. [Methods of bio-chemical analysis of plants. Kiev. "Naukova Dumka", 334 p.];
18. УРНЕВ В.Л., 2018 - Система хранения плодов промышленных сортов яблони различной степени зрелости. Автореф. дис. канд. с-х наук, Мичуринск-наукоград Р.Ф, 22 с. [Storage system for fruits of industrial apple cultivars of various degrees of maturity. Abstract of thesis. dis. cand. agricultural sciences, Michurinsk-Science City Rus. Fed., 22 p.];
19. ФЕТКЕНХОЙЕР Р., 1984 - Хранение плодов / Пер. с немец. И. М Спичкина, под ред. Ульянова А. М., Москва: Колос, 367 с. [Storage fruits/Transl. from German. I. M Spichkina, ed. Ulyanova A. M, Moscow: Kolos, 367 p.]

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