

# Study of Respiration Processes During Storage of Agricultural Raw Materials

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**Abstract:** It has been established that, in the process of respiration, 1 kilogram of potato tubers per 1 hour at 15°C absorbs about 9.4 mg of oxygen and correspondingly releases 10.1 mg of carbon dioxide. Carrots, meanwhile, respire many times more vigorously – 1 kg releases 16.1 mg O<sub>2</sub> and 17.3 mg CO<sub>2</sub>. The respiration of vegetables is most intensive in the first days after harvesting. Temperature has a great influence on the quality of stored vegetable raw materials. As it rises, the intensity of biochemical processes increases, namely the breakdown of complex organic substances, respiratory gas exchange and the associated anaerobic respiration of vegetables. At a temperature close to 0°C, the resistance of vegetable raw materials to natural loss is significantly weakened, despite the suppression of the vital activity of microorganisms. The respiration intensity of vegetable raw materials is affected by various types of damage: mechanical, microbiological and physiological. It has been established that the respiration intensity of many types of vegetable raw materials increases when mechanical damage is inflicted, especially in the initial period, which is due to increased energy expenditure on the biosynthesis of protective substances (suberin, polyphenols, phytoalexins, etc.). The respiration of many types of fruits, including root crops, first increases to a maximum level, after which its intensity decreases. The activity of the malic enzyme can be affected by acids of the tricarboxylic acid cycle. Oxaloacetic, citric, isocitric and  $\alpha$ -ketoglutaric acids are formed in the cycle from malic acid and can inhibit the activity of the malic enzyme. During storage, the respiration intensity of the control and experimental fruits increases over 25–35 days and remains higher in the control samples than in the experimental ones. The change in respiration intensity during storage of clementine and ortanique fruits under mode 1 (R) is identical. During storage, the respiration intensity of the control fruit samples increases and remains higher than that of the experimental ones throughout the entire storage period.

**Keywords:** Vegetables and fruits, storage, ongoing processes, respiration, products after storage, technological modes.

## Introduction:

At present, environmental changes observed on a global scale have a negative impact on the production of agricultural products of sufficient quantity and quality. In particular, the growth of the world's population leads to an increase in demand for food. Vegetables are the main type of food product consumed fresh by the population. This is due to the presence in vegetables of all the vitamins, minerals, pectin substances, etc. necessary for human health. However, there are many problems associated with the use of this type of product in the food industry. One of them is the problem of long-term storage.

Since most vegetable products are grown during a certain period of the year, i.e. a season, the use of modern high-quality long-term storage technologies is simply necessary to supply food industry enterprises with this type of raw material throughout the year. The development of new methods for the storage and processing of agricultural raw materials, aimed at obtaining high-quality functional products through the improvement of technical means and technologies, is becoming increasingly important.

The role of the agro-industrial complex (AIC) in supplying the population's diet with healthy products

will only increase in the coming years, including in the field of vegetable growing. The importance of the AIC for the economy is dictated by the need to ensure the food security of the country, taking into account the changing foreign policy situation and the formation of a sustainable course towards food independence, which has significantly increased the importance of developing vegetable growing and ensuring the availability and price stability of vegetables on the food market. One of the strategic objectives of food security is to provide the population with high-quality agricultural products and food. According to the provisions of the Food Security Doctrine of Uzbekistan, the domestic market should be supplied with domestic agricultural products and food, for the production of which Uzbekistan has favourable conditions. In this regard, research on improving the technologies of long-term storage of vegetable raw materials is relevant and corresponds to the objectives of the state programme for the development of agriculture and the regulation of agricultural product markets.

#### **LITERATURE REVIEW**

During storage, vegetables lose a significant amount of organic substances because various biochemical processes continue to take place in them [1, 2]. This is because after vegetables are removed from the plant, they still remain living organisms, and their vital activity continues even at very low temperatures. In this case, the organic substances in them are consumed for respiration, and therefore part of the water evaporates [3]. These transformations are catalysed by various enzyme systems. It is worth noting that, along with the processes of degradation, processes of synthesis also take place. These processes differ from the synthesis of organic substances in a growing plant in that only chemical transformations of already deposited substances occur [3, 4].

The antioxidant activity and the content of phenolic compounds in vegetable raw materials decrease during storage, as a result of which vegetables begin to spoil much faster [5].

The keeping quality of vegetables and root crops is greatly influenced by their growing conditions, since the processes that took place on the mother plant

continue during storage [6]. The basis of the vital activity of any living organism is respiration, during which the energy contained in organic substances, necessary for all other vital processes, is released [7]. Respiration proceeds differently in different species and varieties of vegetables. According to some data, 1 kilogram of potato tubers per 1 hour at 15°C absorbs about 9.4 mg of oxygen and correspondingly releases 10.1 mg of carbon dioxide. Carrots, meanwhile, respire many times more vigorously – 1 kg absorbs 16.1 mg O<sub>2</sub> and releases 17.3 mg CO<sub>2</sub>. Varietal differences between vegetables are also significant. The process of respiration proceeds differently even in individual tissues of vegetables. Different respiratory quotients have been established for certain tissues.

The respiration of vegetables is most intensive in the first days after harvesting. This effect is due to their reaction to separation from the mother plant. During the period when vegetables emerge from dormancy, the consumption of nutrients increases as a result of intensified respiration [8, 9].

During storage, moisture evaporates from the raw materials, and therefore the normal course of metabolic processes in them is disrupted. As a result, the tissues wilt, the breakdown of organic substances accelerates, and the energy balance is disturbed [10]. After that, the resistance of vegetables to pathogens decreases. Temperature has a great influence on the quality of stored vegetable raw materials. As it rises, the intensity of biochemical processes increases, namely the breakdown of complex organic substances, respiratory gas exchange and the associated anaerobic respiration of vegetables.

During storage, the mass of raw materials decreases mainly due to the evaporation of moisture and only partly as a result of the consumption of organic substances for respiration. This leads to an increase in the relative dry matter content of vegetables. To protect vegetables from wilting, it is necessary to maintain a sufficiently high air humidity in the storage facility and to ensure that the surface of all vegetable raw materials remains dry.

At a temperature close to 0°C, the resistance of vegetable raw materials to natural loss is significantly weakened, despite the suppression of the vital

activity of microorganisms. In addition, in some cases it becomes necessary to store raw materials at a higher temperature. This is because at different temperature levels vegetables use different organic substances for respiration [11].

During storage, vegetables are much more severely affected by pathogenic microorganisms. This process is especially rapid if the raw materials are subjected to even minor mechanical damage [12]. However, in the course of evolution, higher plants have developed defence reactions that determine their resistance to infectious diseases. Disease-resistant varieties of vegetables are capable, while alive, of forming inhibitors under the influence of pathogenic

microorganisms that help to suppress them.

In view of the above, the study of respiration processes during storage of agricultural raw materials appears to be relevant.

**Objects of research.** The following raw materials were used for the experimental studies: carrot roots of the varieties “Kukcha” and “Nurli”; beetroots of the varieties “Uzbekiston 102”, “Samarkand 1” and “Kizil lavlagi”; potato tubers of the varieties “Akrab”, “Zarafshon” and “Umid”.

## METHODS

The physicochemical indicators of the vegetable raw materials were determined in accordance with the regulatory documents presented in Table 1.

**Table 1**

### Methods of research of fruit and vegetable products

| Objects of research | Indicators                               | Methods of determination                                                                                                           |
|---------------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| 1                   | 2                                        | 3                                                                                                                                  |
| Carrot roots        | organoleptic indicators                  | GOST 32284-2013 Fresh table carrots sold in retail trade. Specifications                                                           |
|                     | moisture content (or dry matter content) | GOST 28561-90 Fruit and vegetable products. Methods for determination of dry matter or moisture, standard thermogravimetric method |
|                     | sugar content                            | GOST 8756.13-87 Fruit and vegetable products. Methods for determination of sugars, standard photocolorimetric method               |
|                     | β-carotene content                       | GOST ISO 6558-2-2019 Fruits, vegetables and derived products. Determination of carotene content by the spectrophotometric method   |
|                     | content of pectin substances             | GOST 29059-91 Fruit and vegetable products. Titrimetric method for determination of pectin substances                              |
|                     | content of organic acids                 | GOST ISO 750-2013 Fruit and vegetable products. Determination of titratable acidity by the potentiometric method                   |
|                     | ascorbic acid (vitamin C) content        | GOST 24556-89 Fruit and vegetable products. Methods for determination of vitamin C                                                 |
| Beetroots           | organoleptic indicators                  | GOST 32285-2013 Fresh table beet sold in retail trade. Specifications                                                              |
|                     | moisture (dry matter) content            | GOST 28561-90 Fruit and vegetable products. Methods for determination of dry matter or moisture                                    |
|                     | sugar content                            | GOST 8756.13-87 Fruit and vegetable products. Methods for determination of sugars                                                  |

|          |                                   |                                                                                                                  |
|----------|-----------------------------------|------------------------------------------------------------------------------------------------------------------|
|          | content of organic acids          | GOST ISO 750-2013 Fruit and vegetable products. Determination of titratable acidity by the potentiometric method |
|          | ascorbic acid (vitamin C) content | GOST 24556-89 Fruit and vegetable products. Methods for determination of vitamin C                               |
| Potatoes | organoleptic indicators           | GOST 7176-2017 Ware potatoes. Specifications                                                                     |
|          | moisture (dry matter) content     | GOST 28561-90 Fruit and vegetable products. Methods for determination of dry matter or moisture                  |
|          | sugar content                     | GOST 8756.13-87 Fruit and vegetable products. Methods for determination of sugars                                |
|          | starch                            | GOST 7194-81. Fresh potatoes. Acceptance rules and                                                               |

The information given in Table 1 shows that modern methods of physicochemical analysis regulated by state standards were used in the study of the research objects.

## RESULTS AND DISCUSSION

As a result of respiration, plant cells obtain the energy necessary to maintain their vital activity. At the same time, the significance of respiration is not limited to the supply of energy. Respiration is a complex multistage oxidation–reduction process. At its intermediate stages, during storage of plant raw materials, new organic compounds are formed from reserve nutrients and are then used in various metabolic reactions. Thus, respiration is a source of many metabolites.

The respiration intensity of vegetable raw materials is affected by various types of damage: mechanical, microbiological and physiological. It has been established that the respiration intensity of many types of vegetable raw materials increases when mechanical damage is inflicted, especially in the initial period, which is due to increased energy expenditure on the biosynthesis of protective substances (suberin, polyphenols, phytoalexins, etc.). The intensification of respiration upon damage by agricultural pests, rodents, microorganisms and physiological diseases is explained by energy expenditure on the formation of protective barriers and necroses, the biosynthesis of bactericidal substances and the activation of oxidative enzymes.

The respiration of many types of fruits, including root crops, first increases to a maximum level, after which its intensity decreases. The rise in respiration itself is only an external manifestation of a qualitative restructuring of the biochemical processes taking place in the fruits. The intensification of respiration during fruit ripening is associated with a weakening of the structural integrity of the cell, with the activation of protein synthesis and with the uncoupling of oxidation and phosphorylation. During ripening, the structure and functions of the cell change, especially its permeability.

Fig. 1 shows a scheme of carbon dioxide formation during the respiration of plant products. The increase in respiration intensity during ripening is associated with the activation of the malate system. The key enzyme of this system is the malic enzyme, or decarboxylating malate dehydrogenase. It is generally accepted that the main function of the malic enzyme is to regulate the level of  $C_4$  acids: the enzyme removes excess malic acid by decarboxylating it to  $CO_2$  and pyruvate. This function is of great importance for plant tissues: the malic enzyme is activated in cells precisely during the period when the vacuole differentiates, and it removes excess malic acid that, for one reason or another, has not entered the vacuole. Decarboxylation of malate produces NADPH, which is involved in various biosynthetic reactions. Pyruvate is formed in the course of the malate decarboxylation reaction. The influx of pyruvate entails the activation

of pyruvate decarboxylase and increased formation of acetaldehyde and alcohol.

The activity of the malic enzyme can be affected by acids of the tricarboxylic acid cycle. Oxaloacetic, citric, isocitric and  $\alpha$ -ketoglutaric acids are formed in the

cycle from malic acid and can inhibit the activity of the malic enzyme. Succinic and fumaric acids, the precursors of malic acid in the cycle, activate the enzyme at low substrate concentrations but themselves inhibit its activity.

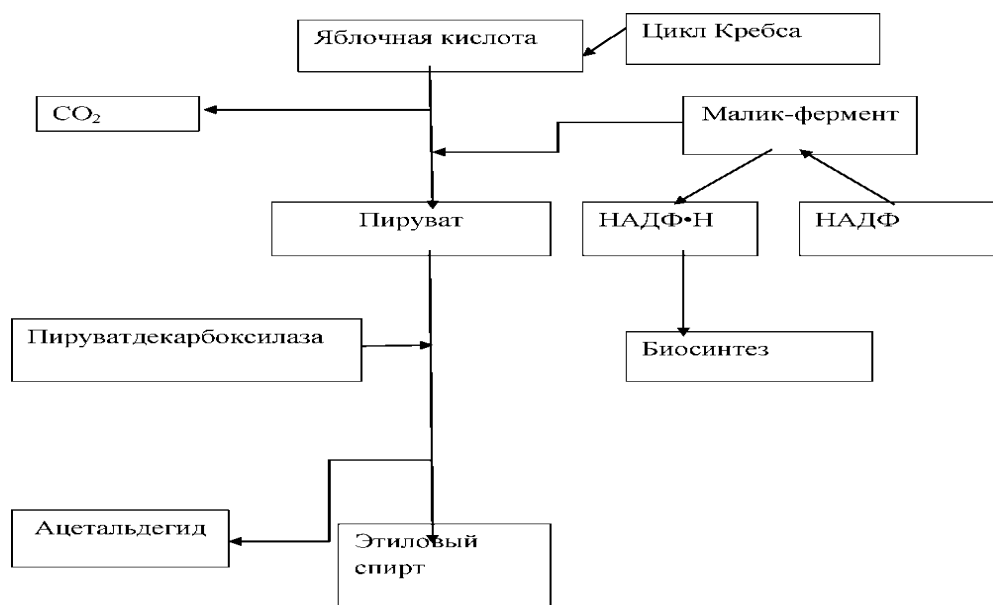


**Figure 1. Scheme of carbon dioxide formation during respiration**

The respiration intensity ( $I_d$ ) of fruits is a metabolic process and characterizes their physiological state, which depends substantially on external factors, in particular temperature and treatment with biopreparations.

The  $I_d$  values of clementine and ortanique fruits do not differ significantly and at a temperature of  $t = (+4 \pm 1)^\circ\text{C}$  are  $(3.8 \pm 0.2)$  and  $(3.5 \pm 0.2)$   $\text{mg CO}_2/(\text{kg} \cdot \text{h})$ .

After treatment of the fruits with biopreparations, the respiration intensity increases within 2 days to  $(4.4 \pm 0.2)$   $\text{mg CO}_2/(\text{kg} \cdot \text{h})$  and  $(3.8 \pm 0.2)$   $\text{mg CO}_2/(\text{kg} \cdot \text{h})$ , and then gradually decreases to the initial values.

Figures 2, 3 and 4 show data on the change in respiration intensity of clementines and ortaniques depending on the type of biopreparation and the duration of their storage.

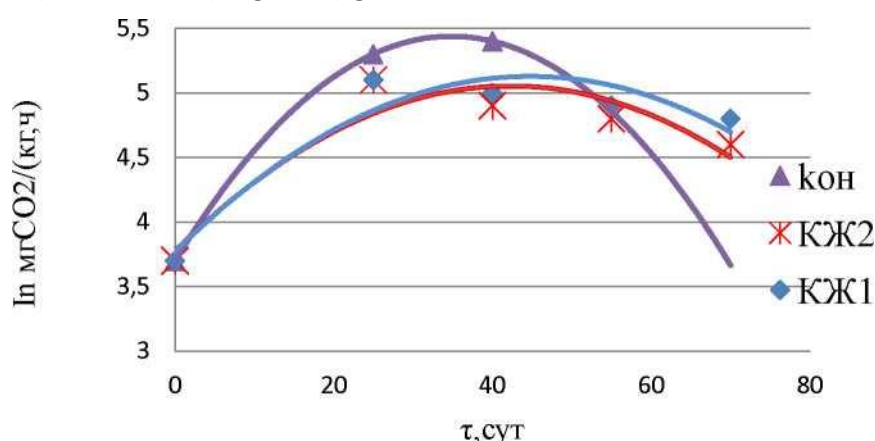


**Figure 2 – Change in respiration intensity ( $I_d$ ) during storage of clementines (R1)**

As follows from Fig. 2, during storage, the respiration intensity of the control and experimental fruits increases over 25–35 days and remains higher in the control samples than in the experimental ones. When the temperature is lowered to  $+4^\circ\text{C}$ , respiration

decreases during further storage of the fruits up to 70 days. In the control fruits, the respiration intensity decreases, which can be explained by the decarboxylation of organic acids and the predominance of anaerobic respiration.

The change in respiration intensity during storage of clementine and ortanique fruits under mode 1 (R) is identical.

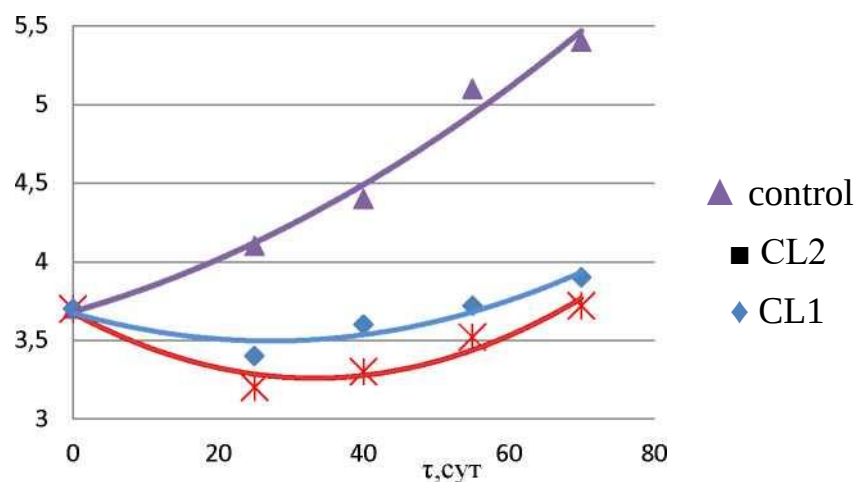


Figure 3 – Change in respiration intensity ( $I_d$ ) of clementine fruits treated with biopreparations depending on storage duration at a temperature of  $t = (+4\pm 1)^\circ\text{C}$  (R2)

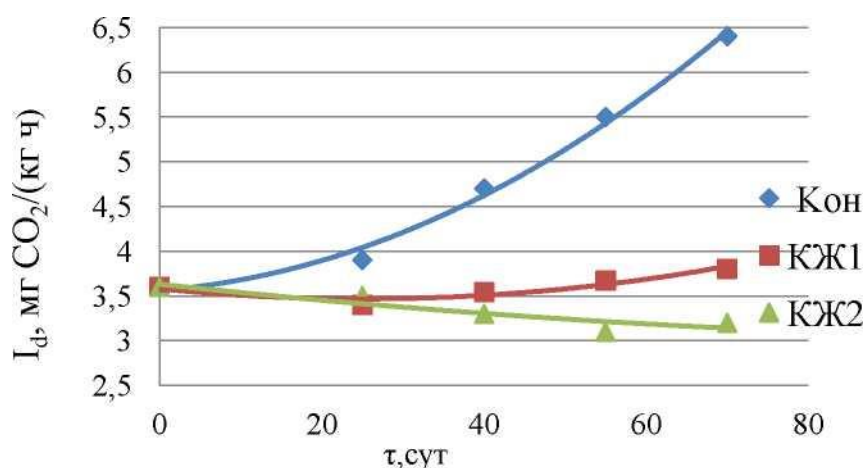


Figure 4 – Change in respiration intensity ( $I_d$ ) of ortanique fruits treated with biopreparations depending on storage duration at a temperature of  $t = (+4\pm 1)^\circ\text{C}$  (R2)

As follows from Figures 3 and 4, during storage, the respiration intensity of the control fruit samples increases and remains higher than that of the experimental ones throughout the entire storage period. The increase in respiration intensity can be explained by a change in the physiological state of the fruits and the development of pathogens on their surface.

No significant differences were found in the respiration intensity of clementine and ortanique fruits treated with CL1 and CL2. The decrease in this indicator during storage of the experimental samples may be associated with the suppression of the activity of pyridine and flavin dehydrogenases, as well as cytochrome oxidases, by the metabolites of

antagonist bacteria.

## CONCLUSIONS

Thus, it can be assumed that it is practically impossible to judge the keeping quality of healthy fruits on the basis of determining their respiration intensity. At the same time, during storage, a prerequisite for protection against diseases is maintaining respiratory gas exchange in the tissues at a certain level, which excludes any disruption in the coordinated operation of the links in the entire chain of biological oxidation. Only under this condition can the resistance inherent in plant tissue be used most fully.

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