



III International Scientific Conference “Sustainable and efficient use  
of energy, water and natural resources – SEWAN-2021”

ГАЛАХИМ



# Biological method of gaseous media formation during cold storage of fruits using track membranes

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Faculty of Biotechnologies (BioTech), ITMO University

### Keywords:

cold storage, gas-selective track membrane (GSTM),  
gas composition, controlled atmosphere, respiratory rate, apples

**Research Objective:** to investigate and substantiate the formation of the gas composition depending on the respiratory rate of fruits and the selectivity of track membranes during cold storage of apples of autumn varieties

**Objects of research:** apples of autumn varieties:



- Grushovka Yudicheva*
- Kordonovka*
- Pepin Shafrannyi*



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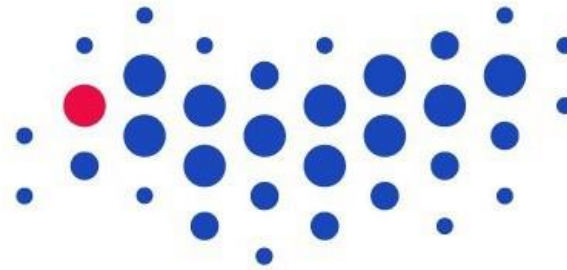
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# Collaborative development:



ITMO UNIVERSITY

## Pavlovsk Experimental Station of Vavilov Institute of Plant Industry



Federal State Unitary Enterprise «S.V. Lebedev Institute of synthetic rubber»



Ioffe Physical-Technical Institute of the Russian Academy of Sciences



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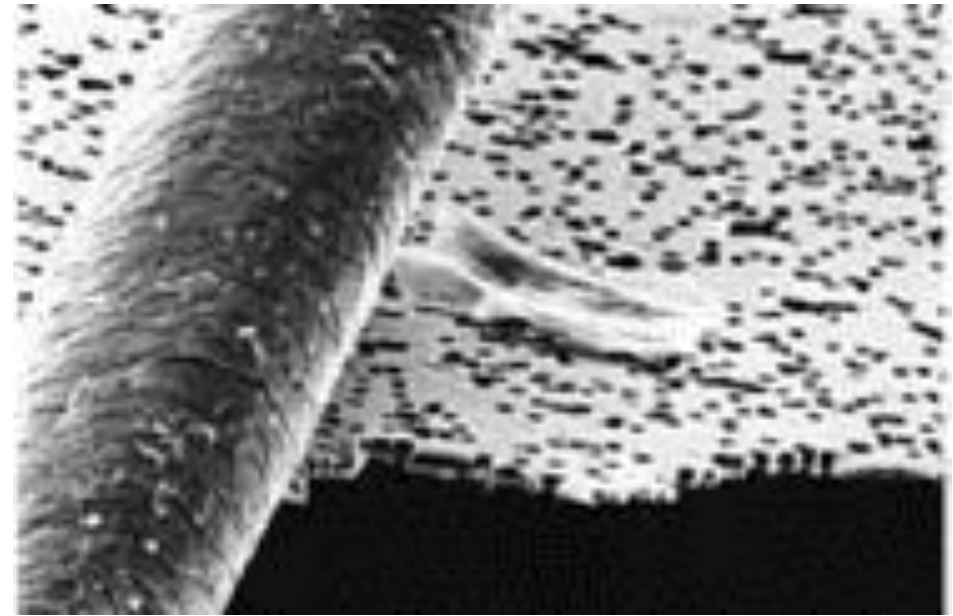
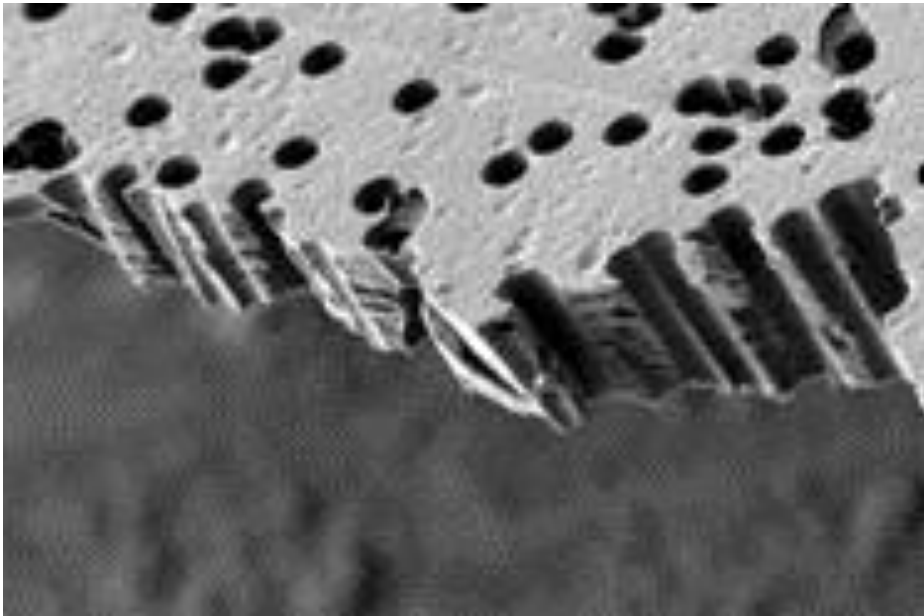
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# Gas-selective membrane material with a track membranes substrate based on polyethylene terephthalate film



PORE DIAMETER 0.2  $\mu\text{m}$

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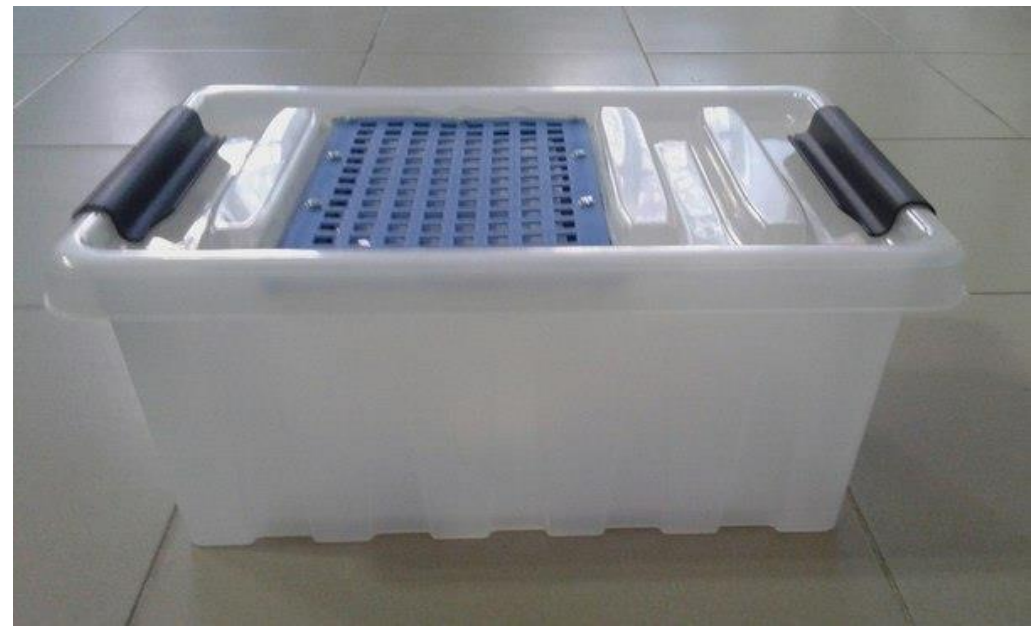
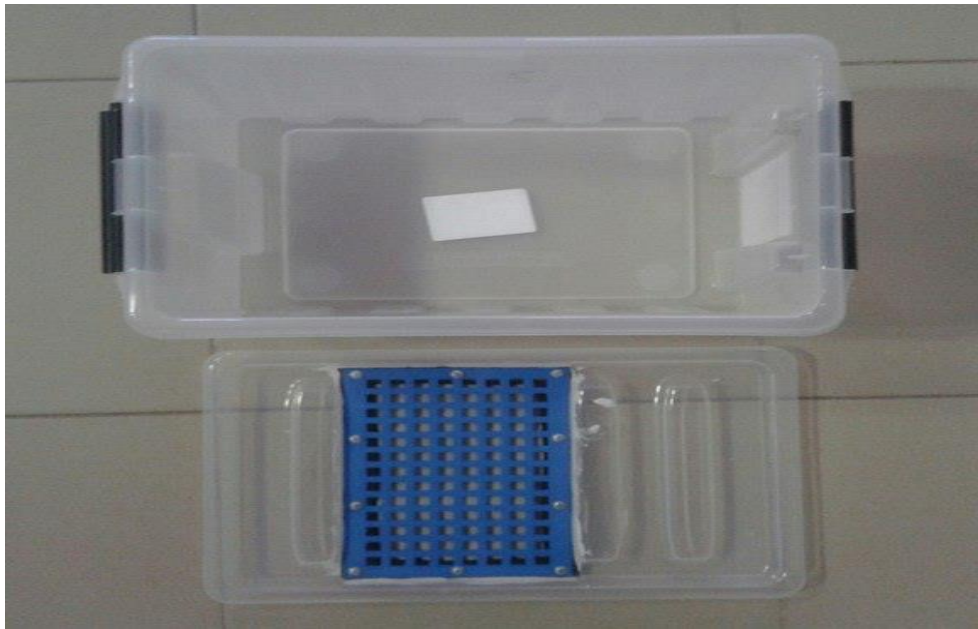
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# Container equipped with GSTM



SELECTIVITY 4,0 – 5,0; LAYER THICKNESS 10  $\mu\text{m}$

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## Calculation of capacity and area of gas-selective track membranes

$$S = \frac{m}{\mu}, \quad \mu = \left( \frac{C_{O_2}^H}{C_{O_2}^K} - 1 \right) \cdot \mu_0, \quad \mu_0 = \frac{pP}{J}, \quad C_{CO_2} = \frac{\delta}{\sigma} (C_{O_2}^H - C_{O_2}^K),$$

 $S$  – membrane area, m<sup>2</sup>; $\mu$  - membrane capacity, kg/m<sup>2</sup>; $C_{O_2}^H$  - initial oxygen concentration (21%); $C_{O_2}^K$  - recommended storage mode, % $p$  - oxygen partial pressure (2,1·10<sup>4</sup> Pa); $P$  - membrane permeability for oxygen [3,0·10<sup>9</sup> m<sup>3</sup>/(s·N)]; $J$  - respiratory rate of fruits [2,66 m<sup>3</sup>/(kg·s)]; $C_{CO_2}$  - carbon dioxide concentration in a stationary mode (2,0 - 0,8%); $\delta$  - respiratory quotient (1,1); $\sigma$  - membrane selectivity (5).

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# Gas composition and membrane area

Gas composition №	$C_{O_2}$ , %	$C_{CO_2}$ , %	S, cm <sup>2</sup> /kg
1	2,0	4,18	4
2	3,0	3,96	7
3	4,0	3,74	10
4	5,0	3,52	18
5	5,5	3,41	20
6	6,0	3,30	22
7	7,0	3,08	25

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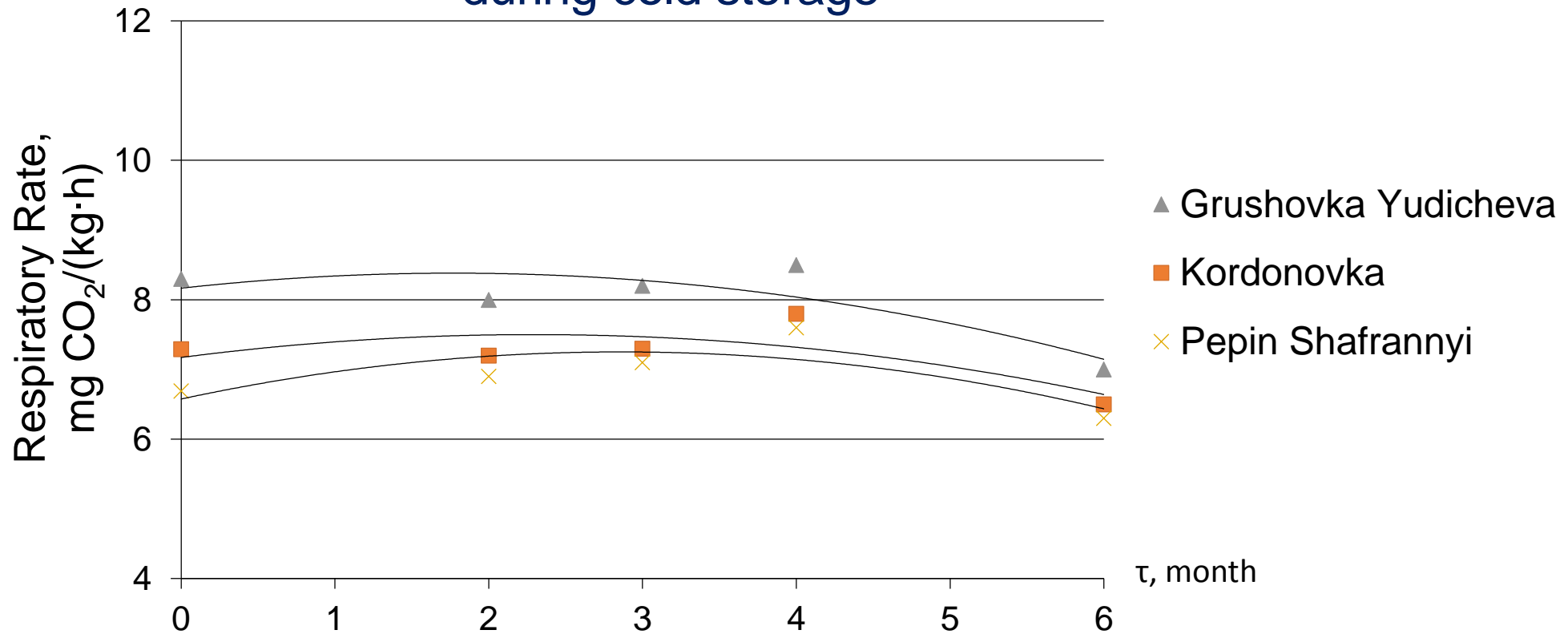
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**Results:**

**Changes in respiratory rate in autumn varieties of apples during cold storage**





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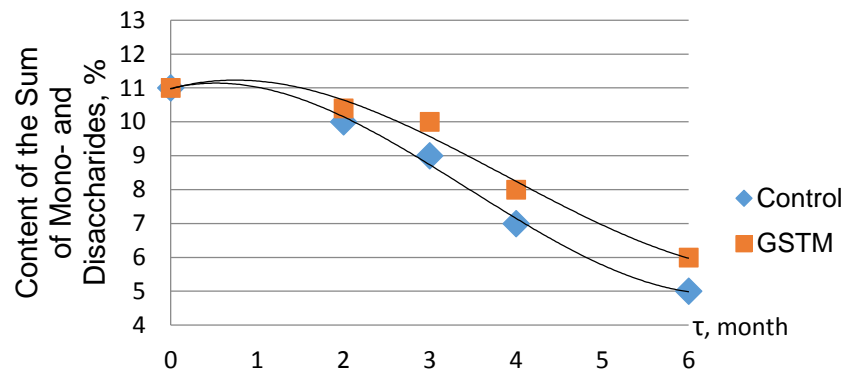
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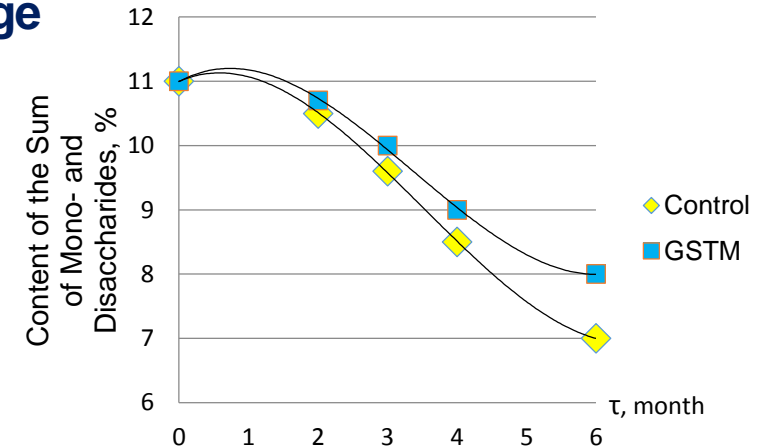
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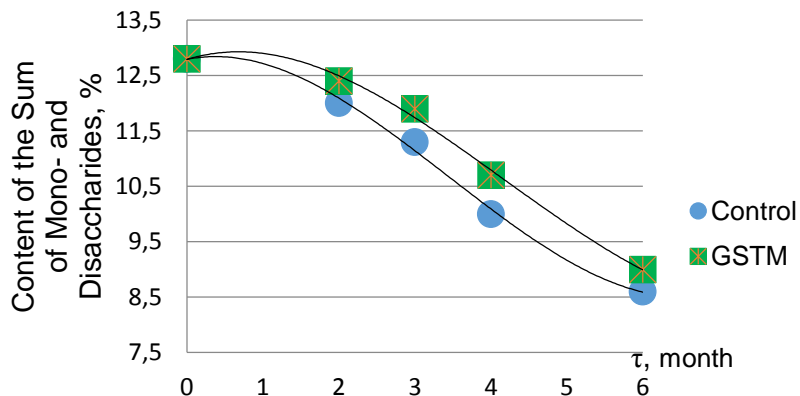
### Kinetic curves of changes in the content of the sum of mono - and disaccharides in apples during cold storage



**Figure 1.** Changes in the content of the sum of mono - and disaccharides in "Kordonovka" apples during cold storage



**Figure 3.** Changes in the content of the sum of mono - and disaccharides in "Pepin Shafrannyi" apples during cold storage



**Figure 2.** Changes in the content of the sum of mono - and disaccharides in "Grushovka Yudicheva" apples during cold storage

### Regression equations characterizing the change in the content of the sum of mono - and disaccharides in apples of the variety:

#### **Kordonovka:**

$$C_{md} = 0,062\tau^3 - 0,65\tau^2 + 0,63\tau + 10,98; R2 = 0,995 \text{ (Control);}$$

$$C_{md} = 0,045\tau^3 - 0,53\tau^2 + 0,72\tau + 10,97; R2 = 0,981 \text{ (GSTM)}$$

#### **Grushovka Yudicheva:**

$$C_{md} = 0,037\tau^3 - 0,39\tau^2 + 0,28\tau + 12,79; R2 = 0,996 \text{ (Control);}$$

$$C_{md} = 0,027\tau^3 - 0,34\tau^2 + 0,42\tau + 12,79; R2 = 0,995 \text{ (GSTM)}$$

#### **Pepin Shafrannyi:**

$$C_{md} = 0,041\tau^3 - 0,44\tau^2 + 0,47\tau + 10,99; R2 = 0,999 \text{ (Control);}$$

$$C_{md} = 0,043\tau^3 - 0,44\tau^2 + 0,58\tau + 10,99; R2 = 0,998 \text{ (GSTM)}$$

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### Rate constants of oxidation reactions of the sum of mono - and disaccharides in apples of autumn varieties during cold storage

Varieties of apples	Storage conditions	$\tau$ , month	$K_1$ , 1/month
<b>Kordonovka</b>	Control	6	0,131
	GSTM	6	0,101
<b>Grushovka Yudicheva</b>	Control	6	0,066
	GSTM	6	0,059
<b>Pepin Shafrannyi</b>	Control	6	0,075
	GSTM	6	0,053

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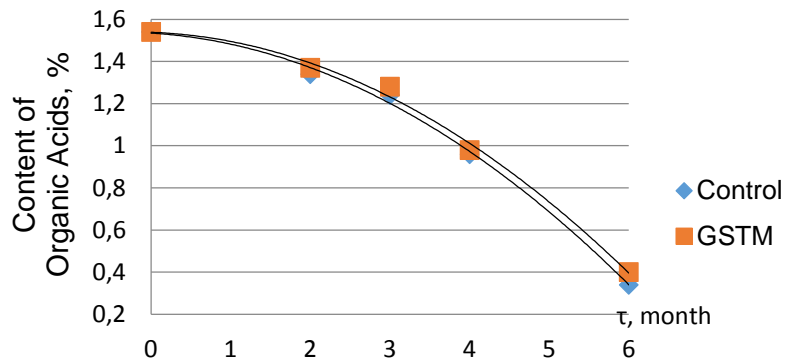
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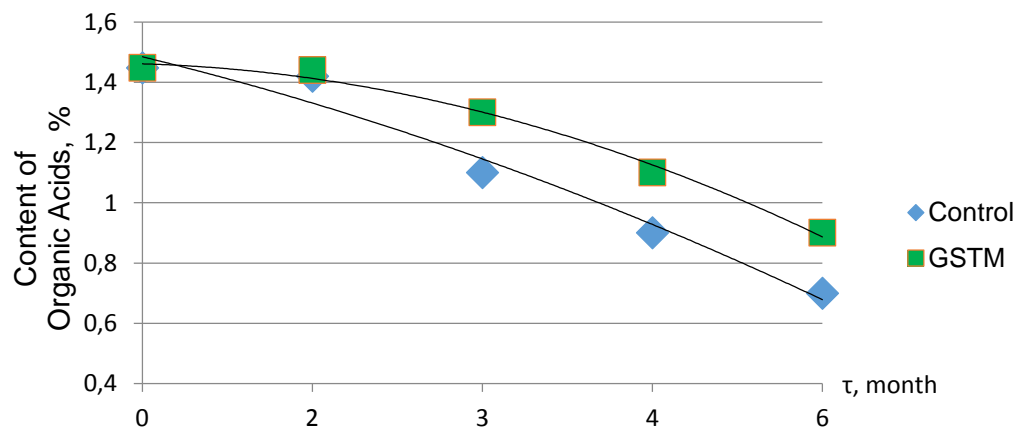
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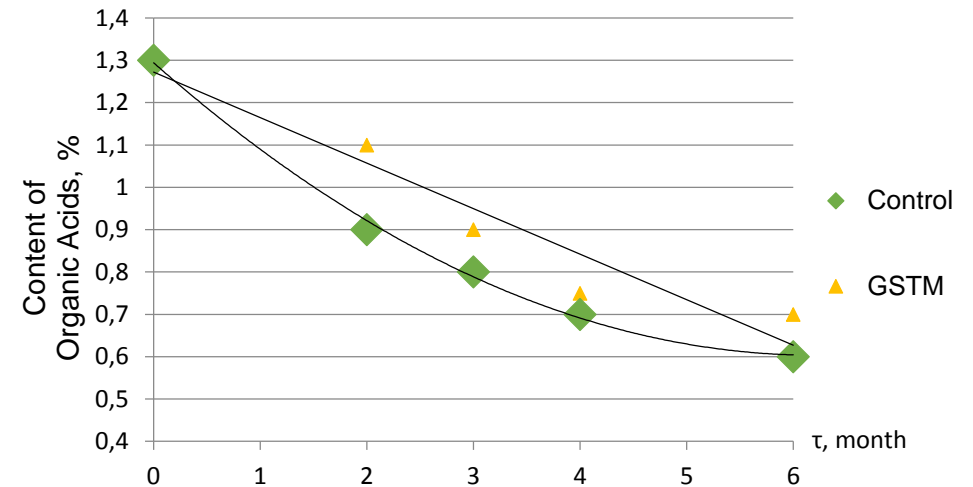
### Kinetic curves of changes in the content of organic acids in apples during cold storage



**Figure 1.** Changes in the content of organic acids in "Kordonovka" apples during cold storage



**Figure 2.** Changes in the content of organic acids in "Grushovka Yudicheva" apples during cold storage



**Figure 3.** Changes in the content of organic acids in "Pepin Shafrannyi" apples during cold storage

### Regression equations characterizing the change in the content of organic acids in apples of the variety:

#### **Kordonovka:**

$$C_{oa} = -0,029\tau^2 - 0,023\tau + 1,53; R^2 = 0,996 \text{ (Control);}$$

$$C_{oa} = 0,029\tau^2 - 0,014\tau + 1,54; R^2 = 0,995 \text{ (GSTM)}$$

#### **Grushovka Yudicheva:**

$$C_{oa} = -0,016\tau^2 - 0,11\tau + 1,61; R^2 = 0,97 \text{ (Control);}$$

$$C_{oa} = -0,031\tau^2 + 0,046\tau + 1,45; R^2 = 0,992 \text{ (GSTM)}$$

#### **Pepin Shafrannyi:**

$$C_{oa} = 0,017\tau^2 - 0,22\tau + 1,29; R^2 = 0,997 \text{ (Control);}$$

$$C_{oa} = 0,01\tau^2 - 0,17\tau + 1,32; R^2 = 0,958 \text{ (GSTM)}$$

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## Rate constants of reactions of changes of organic acids content in apples of autumn varieties during cold storage

Varieties of apples	Storage conditions	$\tau$ , month	$K_2$ , 1/month
<b>Kordonovka</b>	Control	6	0,252
	GSTM	6	0,225
<b>Grushovka Yudicheva</b>	Control	6	0,121
	GSTM	6	0,079
<b>Pepin Shafrannyi</b>	Control	6	0,129
	GSTM	6	0,103

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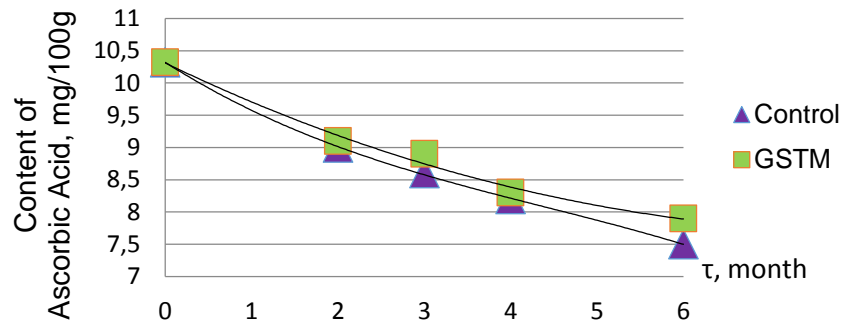
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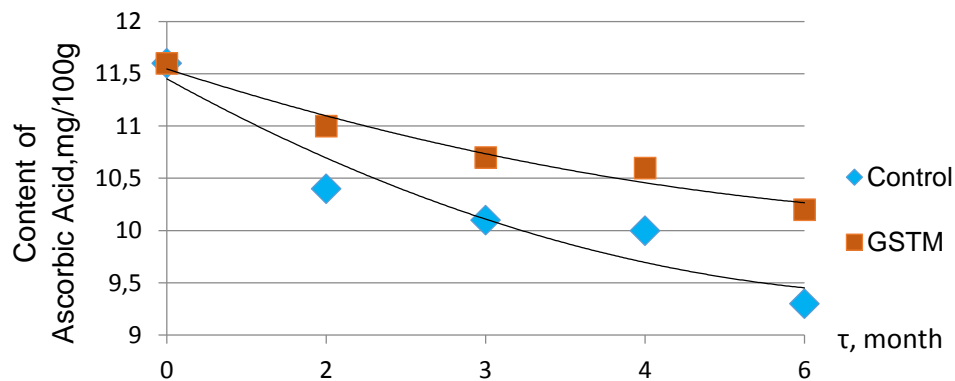
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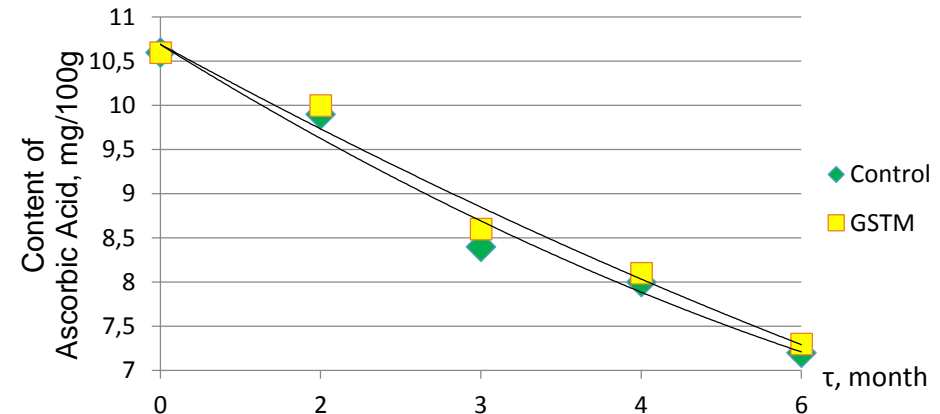
### Kinetic curves of changes in the content of ascorbic acid in apples during cold storage



**Figure 1.** Changes in the content of ascorbic acid in "Kordonovka" apples during cold storage



**Figure 2.** Changes in the content of ascorbic acid in "Grushovka Yudicheva" apples during cold storage



**Figure 3.** Changes in the content of ascorbic acid in "Pepin Shafrannyi" apples during cold storage

### Regression equations characterizing the change in the content of ascorbic acid in apples of the variety:

#### *Kordonovka:*

$$C_{aa} = -0,008\tau^3 + 0,12\tau^2 - 0,85\tau + 10,3; R2 = 0,999 \text{ (Control);}$$

$$C_{aa} = -0,001\tau^3 + 0,043\tau^2 - 0,65\tau + 10,3; R2 = 0,988 \text{ (GSTM)}$$

#### *Grushovka Yudicheva:*

$$C_{aa} = 0,085\tau^2 - 1,01\tau + 12,4; R2 = 0,92 \text{ (Control);}$$

$$C_{aa} = 0,042\tau^2 - 0,58\tau + 12,1; R2 = 0,964 \text{ (GSTM)}$$

#### *Pepin Shafrannyi:*

$$C_{aa} = 0,064\tau^2 - 1,26\tau + 11,9; R2 = 0,976 \text{ (Control);}$$

$$C_{aa} = 0,035\tau^2 - 1,06\tau + 11,7; R2 = 0,98 \text{ (GSTM)}$$

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### Rate constants of reactions of conversion of ascorbic acid content in apples of autumn varieties during cold storage

Varieties of apples	Storage conditions	$\tau$ , month	$K_3$ , 1/month
<b>Kordonovka</b>	Control	6	0,053
	GSTM	6	0,045
<b>Grushovka Yudicheva</b>	Control	6	0,037
	GSTM	6	0,021
<b>Pepin Shafrannyi</b>	Control	6	0,064
	GSTM	6	0,062

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### Phytopathological indicators during cold storage, days

Varieties of apples	60 days			120 days		
	Healthy apples, %	Fusarium culmorum	Monilia fructigena	Healthy apples, %	Fusarium culmorum	Monilia fructigena
	<b>Control</b>					
Kordonovka	94.7	0	4.8	90.2	0	5.3
Grushovka Yudicheva	92.1	1.9	6.0	90.0	3.4	6.6
Pepin Shafrannyi	91.7	2.6	4.8	87.5	4.6	7.9
	<b>GSTM</b>					
Kordonovka	95.2	0	4.2	90.7	0	4.5
Grushovka Yudicheva	97.0	0	3.0	94.2	2.7	5,2
Pepin Shafrannyi	95.4	2.0	2.6	92.0	2.0	2.6

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## Conclusions

It is shown that for maximum preservation of the quality, nutritional and biological value of the studied apple varieties at  $t = (3 \pm 1) ^\circ \text{C}$  a controlled gas atmosphere of the following composition is recommended: oxygen concentration -  $(5.2 \pm 0.1\%)$ , carbon dioxide concentration -  $(3.6 \pm 0.1\%)$ . Controlled atmosphere was created using a gas-selective composite membrane with an area of 14-22 cm<sup>2</sup>/kg, depending on variety of apples and respiratory rate.

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# Thank you for your attention!

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