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Diagnostics of Quality and Prognostic of Potatoes Safe Storage Duration

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The correlation obtained from the accelerated tests on bio-overgrowth, strength change at supression and tubers sprouting at increased temperature and humidity (at 40°C and maximum humidity) allows to determine the following parameters:

- *quality of potatoes installed for storage;*
- *prognosing the time periods of their safe storage;*
- *setting the regime of potatoes delivery according to their quality and the time period of safe storage.*

Keywords Diagnostics; duration; kinetic; potatoes; prognosing; quantitative level; storage

Aims and Background

Potatoes storage is one of the main questions of the policy of agricultural industry in Russia. As it is known, the losses of the harvest are still intolerably high. According to the data of the USSR AgroProm in 1986–1991 these losses were over 20% of the harvest. It should be mentioned, that comparing with 1930 the losses of the potatoes harvest during storage increased by twice, approximately.

The analysis of the materials accessible for us has revealed the following causes of high losses during the storage of potatoes:

- the production of low quality (low stable) sorts;
- the application of mineral fertilizers, non-balanced by their composition. Excessive quantities of nitrogen-containing fertilizers promote the growth of pathogenic microorganism in the potatoes tubers;
- mechanical damages of potatoes tubers during harvesting. On its way from the field to the customer each potato receives approximately 30 blows, 5 kgf strong each;
- imperfect technology of storage.

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During storage potatoes are influenced by various factors (temperature, humidity, mechanical damages, components of gas medium and microorganisms), which cause the initiation and development of biochemical and physico-chemical transformations. As these changes occur during the time of storage and lead to the decrease of marketable properties (nutritious, tasty ones and marketable quality, the "aging" definition is expressive enough for characterization of the present processes. Thus, as aging we consider the combination of biochemical and physico-chemical processes, proceeding in vegetable tissues and leading to irreversible change of nutritious and tasty properties of potatoes.

At intensive influence of microorganisms both from inside and on the surface of tubers, the aging process will be superposed with biodamage, the latter representing the change of marketable properties caused by vital activity of microorganisms. The proceeding of biodamages abruptly shorten the duration of the safe storage. In this case it should be pointed out that the extraction of the products of metabolism strengthens the aging (synergetic effect). Moreover, preserved storage of potatoes is sufficiently defined by the rest period (duration of storage up to the beginning of the plumules growing up on tubers). It is natural to suppose that both aging and biodamaging will influence the duration of the rest period.

Figure 1 shows the main factors, influencing potatoes during storage, the biochemical and physico-chemical processes, proceeding under the influence of these factors and the marketable properties being changed in this case.

The aim of the present paper is the selection of conditions and methods to perform accelerated tests, which would allow to determine the safe storage ability of potatoes during short time at their laying for storage, i.e., the storage duration in conditions of the present store up to the damage of marketable suitability. There are two questions which arise during solving this problem:

- what are the parameters of the properties to be selected for characterization of the biochemical and physico-chemical processes in vegetable tissues of potatoes?
- what are the conditions for the accelerated tests?

To answer the first question it is necessary to clear up, which processes from the above-mentioned play a sufficient role at the change of marketable properties of potatoes.

Processes Proceeding During Potatoes Storage

The processes proceeding during potatoes storage may be subdivided into inevitable processes, i.e., those which cannot be stopped even in optimum conditions of storage (optimum humidity and composition of gas medium, the absence of microorganism and mechanical stresses), and the processes taking part at biodamages and mechanical stresses. The following processes are related to inevitable ones:

- the formation of substances, making worse taste properties and appearance of potatoes (acetaldehyde, lipid peroxides, products of oxidation of polyolefins, quinones, etc.) (see Fig. 2 [1]);
- starch transformation into sugar with its partial decomposition further to carbon dioxide gas and water (see Fig. 3 [2]);
- the decrease of concentration of bio-antioxidants and vitamins, vitamin C first of all;
- the decrease of tubers weight because of diffusional desorption of water and sugar decomposition.

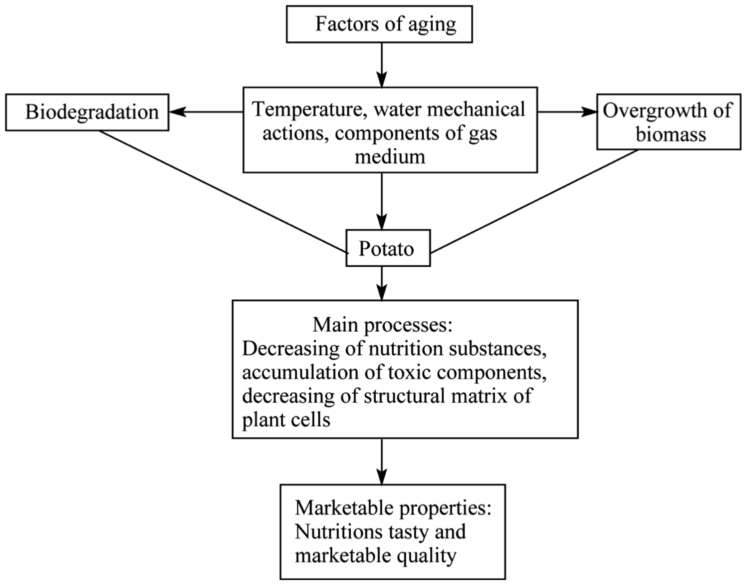

Figure 1. Main factors, influencing potatoes during storage.

With pathogenic microorganisms influencing vegetable tissues of potatoes, there occurs active extraction of metabolism products, organic acids first of all. It also takes place the formation of pectinolythic enzymes which decompose polymers participating in cellular wall of potatoes, hydrolysis of lisosomes entering cytoplasma

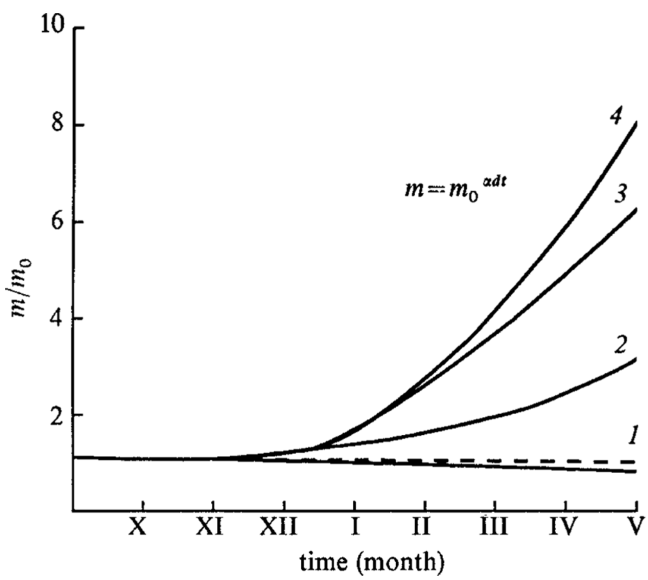

Figure 2. Typical accumulation of substances, making worse taste properties of potatoes in dependence on the storage time: 1 – starch, 2 – acetaldehyde, 3 – lipid peroxides, 4 – products of polyolefines oxidation.

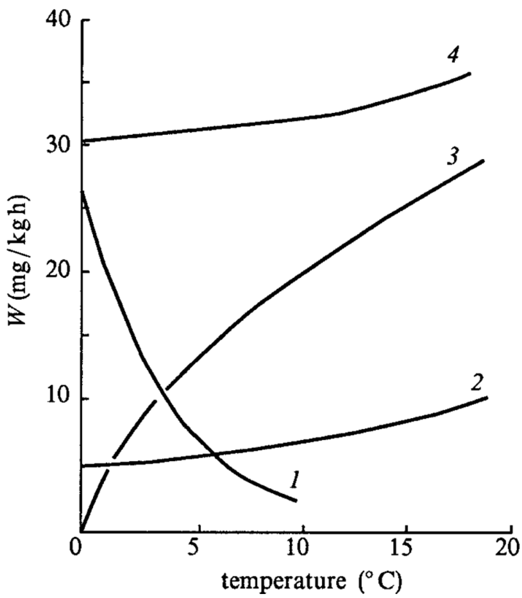

Figure 3. Change of the reaction rates of starch and sugar transformation (W) with temperature: 1 – sugar accumulation, 2 – sugars → CO_2 +H_2O, 3 – sugar → starch, 4 – starch → sugar.

and deorganizing the cell metabolism. A part of the substances of the cell is assimilated by microorganisms directly.

Either the death of pathogenic microorganisms or their further growth with mycelium formation, spore carrying and poisoning the surrounding tubers appear further on in dependence on the value of microbiological load and protective reaction of potatoes (formation of nonspecific cellular antagonists, fitoalexines, and antibiological substances, polyphenols, terpenoids; inhibiting proteolythic enzymes of pathogenic microorganisms). To perform the accelerated tests the following parameters were chosen:

- relative square, occupied by mycelia on the tubers surface – for the estimation of microbiological load and protective reaction of potatoes harvested;
- the mass loss during storage – for determination of the amount of deserted water and volatile products of metabolism;
- the quantity of antioxidants in the peel and the pulp – for estimation of the protective reaction of potatoes;
- strength for suppression – to characterize structural uniformity of potatoes cells.

Methodics of the Performance of Accelerated Tests

In order to perform accelerated tests it is necessary to increase the influence of a single factor or some group of factors. Temperature and humidity may be such factors for the processes of aging, biodamaging and sprouting of potatoes. It may be expected that at temperature increase up to 40°C and relative humidity up to 100% the rate of the above-mentioned factors will increase. Probably, denaturation of proteins, sharp increase of penetrability of the cells membrane and other processes, which are practically absent at temperature below 40°C will take place at temperatures over 40°C.

Experimental

Potatoes of "Lorh" sort of different deliveries were used in experiments after 5–6 month storage. Undamaged tubers were selected. Experiments were performed as follows.

Potatoes were placed into exsiccators containing water in order to provide maximum humidity in the internal volume. Exsiccators were placed into thermoclavs. The experiments were performed at 3, 10, 20 and 40°C. After a definite period of time a part of potatoes tubers was taken off, and the following measurements were performed.

The surface, occupied by biomass of the microorganisms, in % of the total square was determined.

The strength for supression was measured. In this case there were cut the cubes from a tuber with edge size of 20 mm. The curve stress-deformation was recorded by Instron 1122 device.

The curve of the mass loss at constant heating of 10°C/min was recorded on a TA 3000 thermoanalytic system. The value of hanging was 20 mg.

The quantity of antioxidants was determined in the peel and the pulp of potatoes. The hanging of 50 mg was dried in vacuum (10^{-2} torr) until constant mass was reached followed by benzene extraction.

The total concentration of antioxidants was determined at the oxidation of isopropylbenzene in the presence of extracted antioxidants on manometric device [3].

$$\sum \mathbf{C_{InH}} = \frac{\tau \mathbf{W_i}}{2\mathbf{m}\eta}, \tag{1}$$

where τ is the induction period; $\mathbf{W_i}$ is the rate of initiation; $\mathbf{m}$ is the mass of the sample analyzed, η is the drying coefficient.

The calculation was performed in the supposition, that the molecular weight of antioxidants equals 400, and the number of inhibiting groups is $\mathbf{h} = 2$ (inhibiting coefficient equals two).

The time of tubers sprouting was fixed by the occurrence of sprouts of 5 mm long.

Results and Discussion

Figure 4 shows the experimental results for different series of potatoes. As it is seen at drying of potatoes in the atmosphere of saturated water vapours (relative humidity is 0.98–1.00) after some time (lag-phase) the growth of mycelium fungi started on the surface of tubers. At first separate places appeared, which started growing further on. The temperature and, consequently, the value of absolute humidity influence sufficiently the rate of the biomass growth.

To determine the time of the safe storage of potatoes it has been selected the time period of the lag-phase, which value depends on the amount of bacteria and spores of microscopic fungi on the surface of tubers and on the protective reaction of potatoes of the present series.

Figure 5 shows the curves of stress-deformation kind for the samples, cut from the tubers, and the dependence of the break stress on the incubation time. In this case

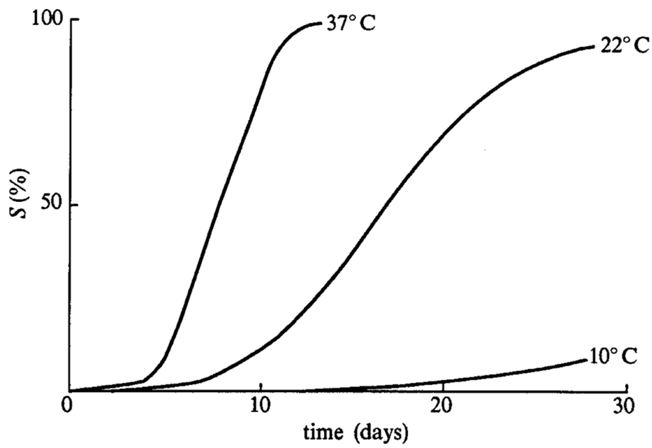

Figure 4. Kinetic curves overgrowth (S) on the surface of tubers at different temperatures and 90% relative humidity without active ventilation.

an induction period occurs also, after which the value of the break stress decreases, being the higher, the higher the storage temperature is.

The curves of the mass losses at constant heating from room temperature up to 400°C display no sufficient differences between the initial potatoes and those, treated by intensive aging and biodamaging (Fig. 6). Thus, the decrease of the potatoes mass during storage is connected with the slow diffusional desorption of water from potatoes tubers.

Potatoes sprouting in the experiments of the accelerated aging and biodamaging show also sufficient induction periods. However, their values do not correlate with the above mentioned data. Figure 7 shows numerous literature data [5–7] on the sprouting of potatoes of different sorts during storage in various temperature conditions, but unfortunately in conditions of noncontrolled humidity. The dependences possess similar view.

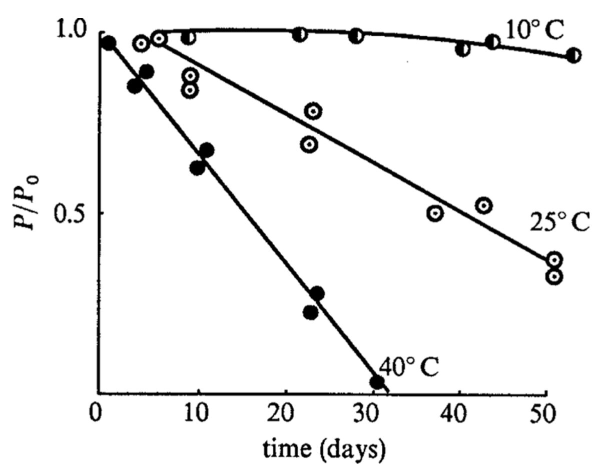

Figure 5. Curves of relative stress-deformation $\left(\frac{P}{P_0}\right)$ versus time storage at different temperatures (potatoes sort – "Lorch").

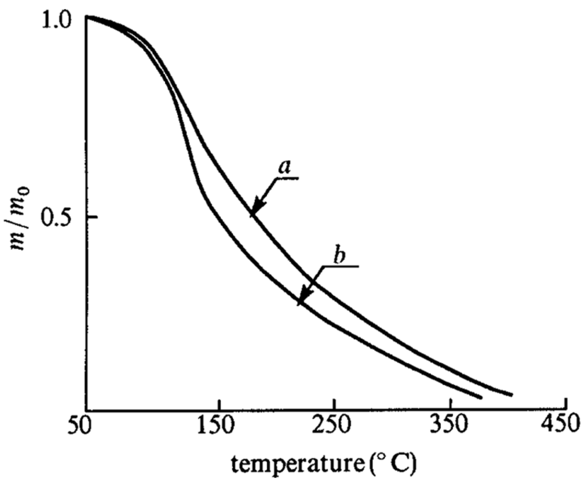

Figure 6. Gravimetric curves of potatoes mass loss at different temperatures: a – samples from undamaged tubers, b – samples from mycellar damaged tubers.

During the potatoes storage the amount of antioxidants decreases abruptly (Fig. 8). However the data show a wide-range dispersion. This may be connected with non-equilibrium distribution of antioxidants in the potatoes tuber.

The analysis of literature and our experimental data show that three processes influence the safe storage of potatoes during storing: aging, biodamaging and sprouting.

The safe storage of potatoes will be estimated by three parameters: the amount of biomass of microorganism on the tubers surface, the strength for supression and time period before sprouting. Lets accept that each of these parameters is unfluenced by the three above mentioned processes. The intensity of proceeding of each of these processes depends on the sort of potatoes, conditions of its growing and storage.

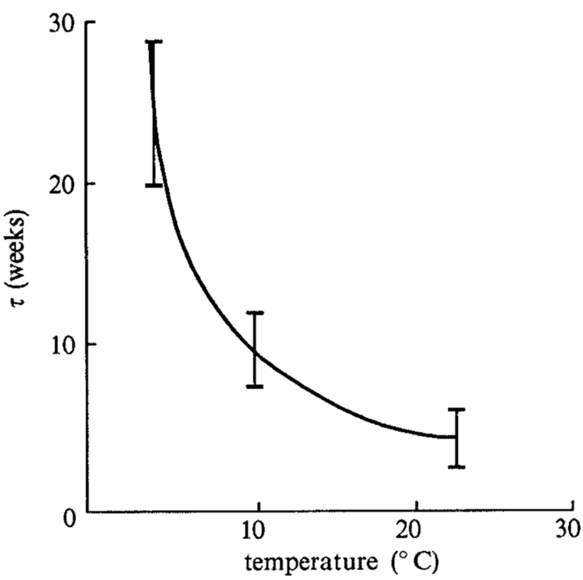

Figure 7. Sprouting time of potatoes of different sorts during storage versus temperature.

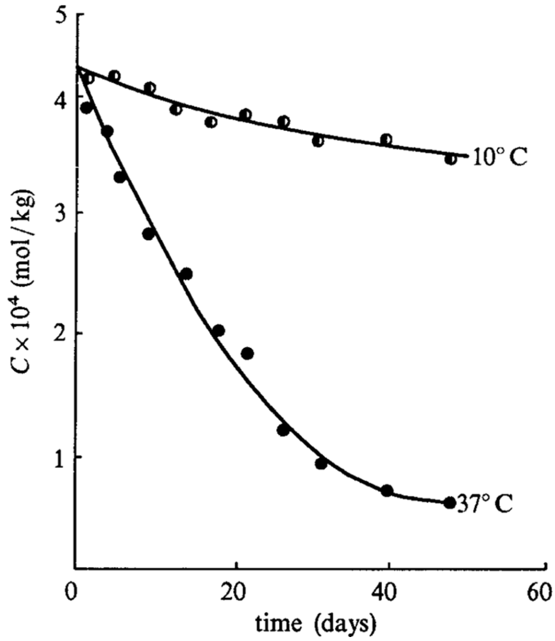

Figure 8. Antioxidant concentration in the potatoes tubers versus time storage at different temperatures.

The data [7] for the change of the potatoes losses during storage in vegetable stores of Gorky city in 1982–1983 season allow to make the following two conclusions:

- the losses of potatoes increase with the storage time (Fig. 9);
- the losses of potatoes at the same time of storage increase with the increase of the amount of initial damaged potatoes (mechanical damages and illness affected) (Fig. 10).

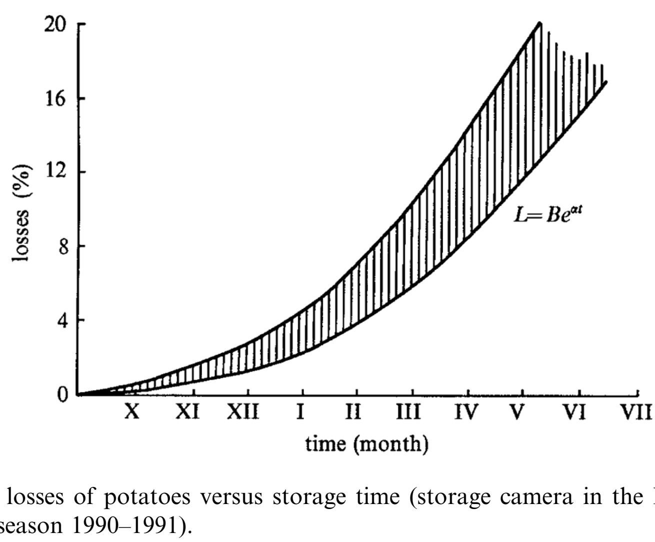

Figure 9. The losses of potatoes versus storage time (storage camera in the Middle Russia, town Gorkii, season 1990–1991).

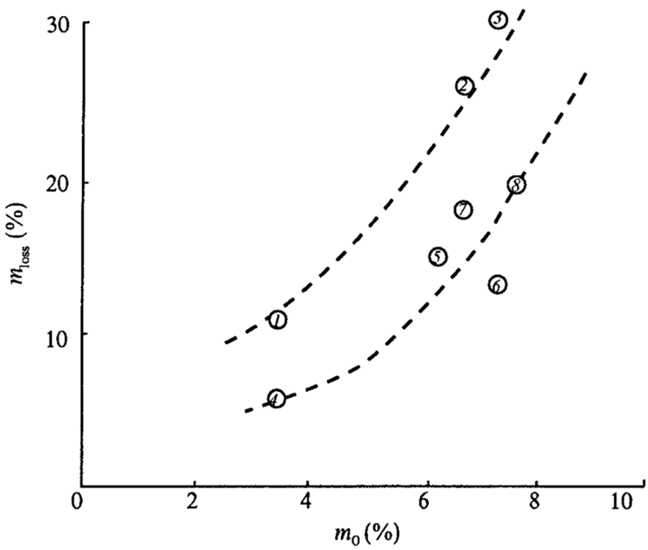

Figure 10. The losses of potatoes versus initial damages and illness affected mass (town Gorkii for different regions 1–8, season of storage 1991–1992).

The data obtained may be satisfactorily described by formally kinetic equation:

$$\mathbf{m} = \mathbf{m}_0 \mathbf{exp}[\boldsymbol{\alpha}(\mathbf{t} - \mathbf{t}^*)], \tag{2}$$

where **m** is the losses of potatoes during storage in % from the initial mass, $\mathbf{m}_0$ is the amount of damaged potatoes in % from the initial mass; $\mathbf{t}^*$ is the induction period, determined experimentally at crossing of the dependence lg$\mathbf{m} - \mathbf{t}$ with the absciss axis; $\boldsymbol{\alpha}$ is a coefficient; **t** is the storage duration.

It may be accepted that the parameters characterizing the safe storage ability of potatoes will change according to the same law:

$$\mathbf{Y} = \mathbf{Y}_0 \exp[\boldsymbol{\alpha}(\mathbf{t} - \mathbf{t}^*)], \tag{3}$$

where $\mathbf{Y}_0$ and **Y** are initial and particular values of **Y** parameter, respectively.

The initial part of the kinetic curves of strength change at supression and bio-overgrowth of tubers during the potatoes storage at increased temperatures and humidity may be described in the coordinates of Eq. (3).

The determination of the dependence of induction periods at the change of temperature and absolute air humidity are of practical interest [8–10].

Let accept that the value of the induction period will decrease with the increase of temperature according to exponential law and with the increase of humidity according to linear law:

$$\mathbf{t}^* = \mathbf{t}_0^* \exp\left(\frac{\mathbf{E}}{\mathbf{RT}}\right) \frac{1}{\gamma \boldsymbol{\varphi}_{\mathbf{H_2O}}}, \tag{4}$$

where **E** is the efficient activation energy; **R** is the gas constant; $\mathbf{t}_0^*$ is the pre-exponential factor; γ is a coefficient; $\boldsymbol{\varphi}_{\mathbf{H_2O}}$ is the absolute air humidity.

Table 1. Duration of induction periods for the processes of bio-overgrowth, the change of strength at suppression and tubers sprouting during storage at different temperatures and air humidities

Process	Temperature, °C	Absolute humidity, $\varphi_{H_2O} \times 10^3$, Pa	Duration of the induction period, days
Bio-overgrowth	10	1.2	18
	22	2.5	7
	37	6.0	3
Strength change at suppression	25	3.0	7 (14)
	40	7.1	3 (7)
Tuber sprouting	3	0.7	160
	10	1.2	80
	25	3.0	40

The analysis of the data in Table 1 shows that the duration of the induction period for the processes studied at different temperatures is inversely proportional to the absolute air humidity, the values $\exp\left(\frac{E}{RT}\right)$ and γ being equal to the unit practically. Thus, there exists a simple correlation:

$$\lg \mathbf{t}^* - \lg \varphi_{H_2O} \approx \text{const} \tag{5}$$

Table 2 shows the corresponding values of $\lg \mathbf{t}^*$ for different processes during storage of potatoes and $\lg \varphi_{H_2O}$ ones for conditions of their proceeding.

Thus, the correlation obtained from the accelerated tests on bio-overgrowth, strength change at supression and tubers sprouting at increased temperature and humidity (at 40°C and maximum humidity) allows to determine the following parameters:

- quality of potatoes installed for storage;
- prognosing the time periods of their safe storage;
- setting the regime of potatoes delivery according to their quality and the time period of safe storage.

Table 2. The correlation between logarithm of induction periods for the processes proceeding during storage of potatoes, and that of absolute air humidity in the storage zone

Process	Temperature, °C	$\lg \mathbf{t}^*$	$\lg \varphi_{H_2O} \times 10^3$	$\lg \mathbf{t}^* + \lg \varphi_{H_2O}$
Bio-overgrowth	10	1.25	3.06	4.31
	22	0.84	3.40	4.24
	37	0.50	3.78	4.28
Strength change at suppression	25	0.84 (1.1)	3.48	4.32 (4.58)
	40	0.50 (0.7)	3.85	4.35 (4.55)
Tubers sprouting	3	2.20	2.85	5.05
	10	1.90	3.06	4.96
	25	1.60	3.48	5.08

References

[1] Kretovich, V. L. (1973). *Technical Biochemistry*, Vysshaya Shkola Publishers: Moscow, USSR.
[2] Chalenko, G. I. & Ozeretskovskaya, O. L. (1975). *Methods of Modern Biochemistry*, Nauka Publishers: Moscow, USSR.
[3] Emanuel, N. M., Zaikov, G. E., & Maizus, Z. K. (1984). *Oxidation of Organic Compounds. Medium Effect in Radical Reactions*, Pergamon Press: Oxford, UK.
[4] Volkind, I. L. (1981). *Complexes for Potatoes Storage*, Koloss Publishers: Leningrad, USSR.
[5] Metlitskii, L. V. & Volkind, I. L. (1967). *Storage of Potatoes and Vegetables*, Koloss Publishers: Leningrad, USSR.
[6] Golovkin, N. A. (1984). *Technology of Food Products*, Pishchevaya Promyshlennost' Publishers: Moscow, USSR.
[7] Rusley, N. I. (1988). *Storage of Potatoes*, Agropromizdat Publishers: Moscow, USSR.
[8] Varfolomeev, S. D., Burlakova, E. B., Popov, A. A., & Zaikov, G. E. (2009). *Biochemical Physics Research Trend*, Nova Science Publishers: New York, USA.
[9] Yuryev, V. P., Tomasik, P., Blennow, A., Wasserman, L. A., & Zaikov, G. E. (2009). *Selected Investigations in the Field of Starch Science*, Nova Science Publishers: New York, USA.
[10] Zaikov, G. E. & Krylova, L. P. (2009). *Biotechnology, Biodegradation, Water and Foodstuffs*, Nova Science Publishers: New York, USA.