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THE USE OF POTASSIUM SALTS UNIQUE PROPERTIES FOR SUPPRESSION OF POTATO PATHOGENS DURING STORAGE PERIOD

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ABSTRACT

Natural sylvinite has the property to produce light air ions due to air molecules contact with potassium and sodium cations. Such environment has the ability to inhibit the growth of potato pathogens. In given report the results of different methods of medium saturation with light negative ions are presented. The studied treatments were following: the surface from bulk sylvinite; aerosol generator (blowing air through salt filters). The filters with lumpy sylvinite filling and special pills from pressed sylvinite were used. Various modes of airing regimes were evaluated – three and six hours a day. The safety of tubers for the storage period, as well as the qualitative set of potato pathogens were assessed. The least number of infected tubers was noted in treatments with “pill”salt filter with three hours ventilation regime and the surface from bulk sylvinite (0.56 and 0.57%, respectively), the largest number of diseased tubers - in the control variant - 1.18%. The smallest mass loss of tubers in the period from January 29 to April 14 was recorded in the treatment with pill salt filter with with three hours ventilation regime - 1.53%, the maximum loss - when using a surface from bulk sylvinite - 2.9%. After studies in typical storages equipped with standard ventilation systems, a technology for potato storage, based on the creation favorable air environment saturated with negative air ions and saline aerosol, will be developed.

Key words: *potato storage, sylvinite, air ions, salt aerosol, potato pathogens.*

INTRODUCTION

Plant protection and preservation of the grown yield are urgent problems of agricultural production, as well as minimizing storage losses, which can reach 30-50 percent (Makarova et.al., 2017). A distinctive feature of the potato storage period is its long duration (7-8 months). During this time, complex biochemical processes take place in the tubers, pathogenic microorganisms often develop in the potato mound, tubers of some varieties begin to germinate already in the middle of the main storage period. Application of different chemical preparations including pesticides, inhibitors etc., should be restricted. The development of systems and measures aimed to grow environmentally friendly products and to reduce the pesticide load on biocenoses has been intensified in recent years due to tightening environmental requirements for agricultural production. Some research works (Sharav'iev et al., 2014) showed the positive effect of ozonizer use on potato tubers safety during storage. The use of bactericidal properties of the air contacting with natural potassium salts is considered to be one of the most promising technologies in potato storage (Nakaryakov, 2017). One of the largest deposits of potassium, magnesium and sodium salts, located in Russia - Verhnekamskoe, contains a third of the world's reserves, which are mainly used for potassium fertilizers production. However, the unique physical and chemical properties of these salts, can significantly expand their use. Natural sylvinite has the property to produce light air ions due to air molecules contact with potassium and sodium cations. Such environment has the ability to inhibit the growth of potato pathogens (Krasnoshtein et.al., 2008). Preliminary studies fulfilled in Perm Federal Research Center showed that microorganisms colonies number in the air medium saturated with light negative ions and salt aerosol decreased by 13-25% compared with the control (Shalimov, et al., 2019).

In this regard, the purpose of this research is to study the impact of these factors on the microclimate of the storage, the ability to inhibit the development of the main pathogens during potato storage, preservation of potato tubers during storage and to test different methods of medium saturation with salt aerosol and light negative ions.

MATERIALS AND METHODS

In the fall of 2020, a batch of seed potato (variety Gornyak) was placed to typical storage area of 280 m^2. The storage was equipped with active ventilation system and thermal insulation (6 cm layer of polyurethane spraying). The experiment with potato storing was fulfilled in six isolated laboratory modules (six treatments) area of 12 m^2 each, installed in the potato storage.

Experiment scheme:

Treatment 1 - control (storage of seed potato, without potassium salts use);

Treatment 2 - ozonizer use (airing regime: two times a week, three hours a day);

Treatment 3 - aerosol generator (blowing air through "pill"salt filter and the subsequent infiltration of the aerosol through the potato mass.), daily, six hours a day

Treatment 4 - aerosol generator - ("pill" salt filter), daily, three hours a day

Treatment 5 - aerosol generator (filter with lumpy sylvinite filling), daily, six hours a day

Treatment 6 – the use of surface from bulk sylvinite.

16 nets with 30 kg potato tubers were stacked in 4 rows on pallets in every laboratory modules. According Standard GOST R 51 706-2001 and Sharav'iev et al., (2014), ozonizer use in storage facilities limited to two times a week. In

Treatment 6 bulk sylvinite was placed on special pallets around the pallet with potato. The microclimate regime in the storehouse (temperature, relative air humidity) was monitored with a “Testo” temperature and humidity meter, CO_2 concentration was determined by gas analyzer “Testo”, the concentration of aeroions - by "Sapphire-3M" air ion register. The microclimate parameters were recorded daily in the "Microclimate control journal ".
Preservation capacity of potato during storage was evaluated on five-point scale according national standard of variety testing. The counting of the natural loss of tubers mass during the storage was carried out by weighing the entire batch of tubers in all treatments at the beginning and in the end of the storage. The tubers biochemical content was determined during storage, including: starch (by polarimetric method), dry matter (by weight method), nitrates (potentiometric according national standard GOST 13496.19-2015). Tubers for analyzes were sampled from the surface and from the depth of the stack - 10 pieces from every variant for each analysis. Sampling was carried out monthly. The following potato diseases were taken into account: *Phytophthora infestans, Phoma exiqua, Rhizoctonia solani, Pseudomonas solanacearum, Corynebacterium sepedonicum, Fusarium spp., Streptomyces spp.* The phytopathogens determination in the infected material was carried out according to morphological characteristics and microscopy observation data. Phytopathogen cultures were isolated by direct seeding on selective media (potato agar and Chapek’s medium) from potato tubers with characteristic signs of diseases.
Biochemical analyzes were carried out in analytical laboratory of Perm Agricultural Research Institute, potato pathogens species – in the Institute of Ecology and Genetics of Microorganisms, both - the divisions of PFRC. Data processing included analysis of variance using the program SPSS (v.18).

RESULTS AND DISCUSSION

The experiments on the effect of the air medium contacting with natural potassium salts on potato storing in special climatic chamber were started in 2017 (Shalimov, et al., 2019) and continued in 2020 in typical storage. In particular, at this stage of research, the use of various methods of saturating the air medium with negative air ions and salt aerosol was studied.
The results of light air ions estimation in storage modules with different methods of medium saturation with light negative ions are presented on the Figure 1.

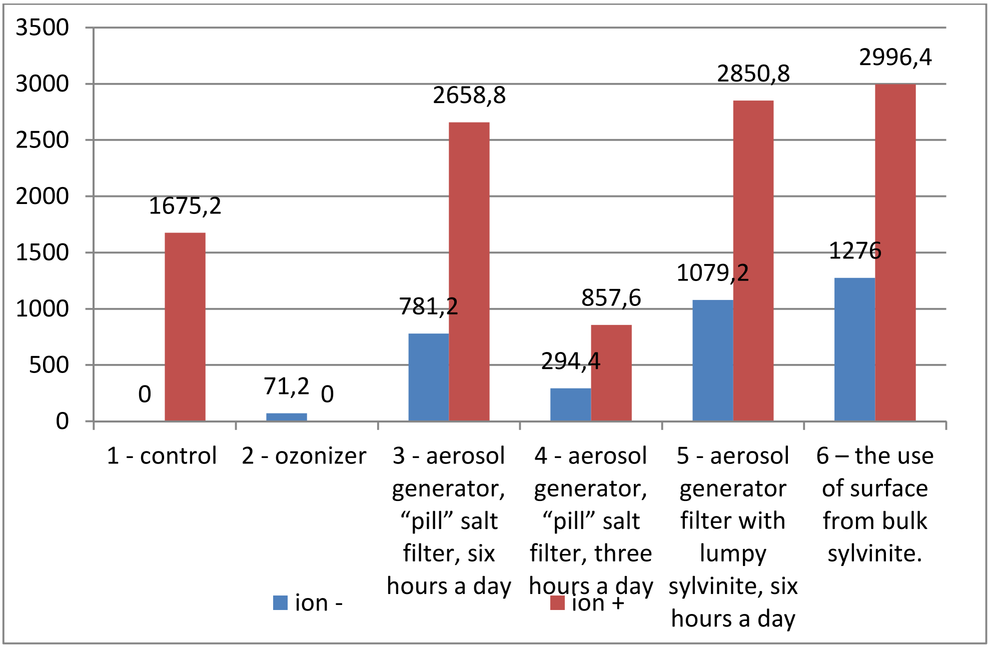

Figure 1. Results of light air ions estimation.

Comparing the measurement results, it can be noted that in all cases the number of positive air ions prevails over negative. Given fact needs an explanation. The process of ions formation is mainly due to the presence in the salts of the potassium isotope K-40, possessing radioactivity (beta and gamma radiation). Ionizing radiation, interacting with air molecules, “knocks out” electrons from them. A positive charge remains on the molecule, while the electron is captured by the electron-acceptor molecule and charges it negatively. N_2 is usually taken as the basis for the positive ion, and O_2 - for the negative ion. Taking into account the real gases content in the atmosphere (nitrogen 78%, oxygen 21%) the greater probability of the meeting of an ionizing particle or a quantum of radiation with a nitrogen molecule take place. Faynburg et al., 2008). Herewith, the radiation influence of natural potassium salts to humans does not exceed the corresponding allowable limits regulated by national Sanitary Rules (SR 2.6.1.758-99) which is due to the fact that potassium isotope content in the total mass of potassium is about 0.012 percent. The maximum amount of negative air ions and ions total amount was recorded in storage with bulk surface - 4272 per cm^3, then in treatment with salt filter with lumpy sylvinite (with air supply for six hours) - 3930 ions per cm^3. The use of “pill” salt filter and air supply for six hours ensured the concentration 3440 e / cm^3. A similar filter, but with air supply for three hours, provided 1152 e / cm^3. The open sylvinite surface allows reaching the maximum values of light air ions in the atmosphere of the storage facility; however, from a practical point of view, it is more convenient to use salt filters. This is due to the fact that the relative air humidity in potato storages usually 90–95%, while the critical air humidity (at which the dissolution of the mineral begins) for sylvinite is 70%. Thus, there is a risk that any sylvinite surface with a moisture content exceeding the critical value will be subject to partial dissolution.

Experiments with a sylvinite bulk surface showed that moisture accumulated on the floor in the test module, which was periodically removed. The use of salt filters avoids these risks. In addition, salt filters with compressed "pills" will allow changing the concentration of light air ions in the atmosphere by changing the pills composition, adding or reducing the amount of the component with K-40 presence.

All the necessary storage periods (treatment period, cooling, basic period, spring period) were maintained The microclimate formed in the experimental stands had insignificant differences among variants, with exception of relative air humidity (RAH).

The air temperature during the treatment period was 15°C, during the cooling - 11.4-10° C. In the basic period it changed by months, in October - 6.5C, in November - dropped from 6.0 to 2.7°C, in spring- increased from 4.3 to 18˚C. The minimum temperature was observed from December to March, inclusive, and amounted to 2.3-3.7°C. With outside temperature rise, the temperature rise inside the storage was noted. In April, the air temperature was 4.3-7.3 ˚C. In the first decades of May, the maximum temperature was 11-18 ˚C .

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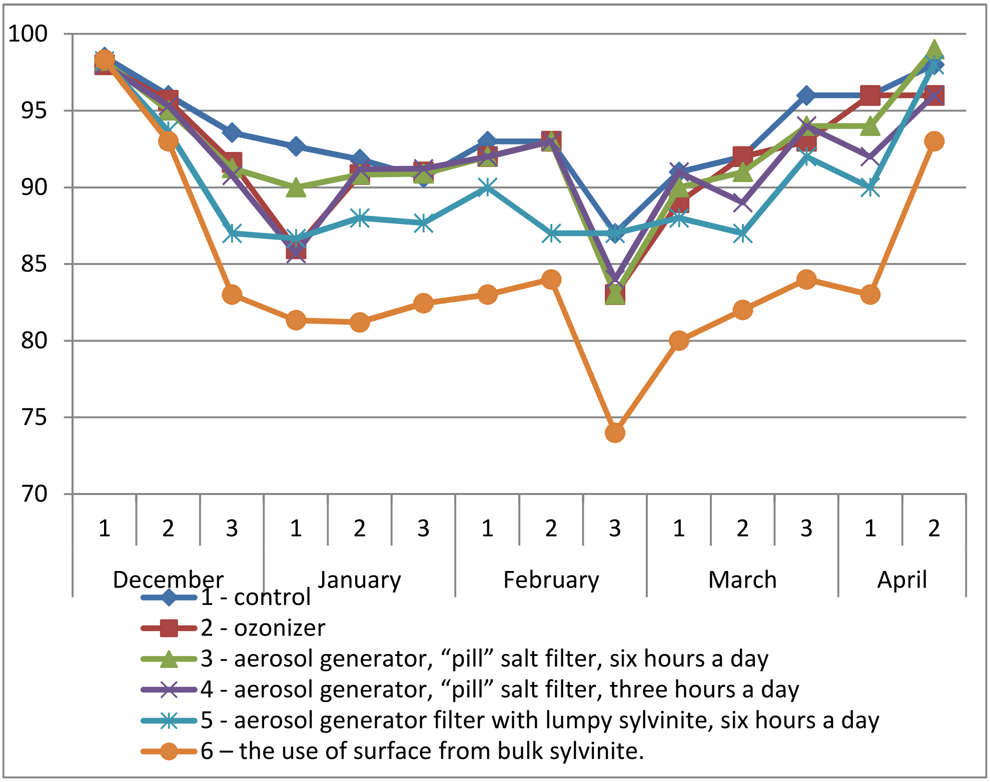

Figure 2. Dynamics of relative air humidity during the storage period.

RAH for the storage period from October to the first decade of December varied from 86 to 98 %, in the next period gradual decrease was noted. The lowest humidity was recorded in late February - early March: 74- 87%, depending on treatments. Maximum humidity (87-98%) during the entire storage period was noted at the control. RAH varied from 83 to 99% when using an ozonizer and “pills” salt filters. The lowest humidity was noted in the treatment with bulk surface of potassium salt 74-98% (Figure 2). The carbon dioxide content varied from 0.078 to 0.127%. The minimum concentration was recorded from February to the first ten days of April (the temperature in the storage facility during this period was minimal). With an increase in storage temperature, the concentration of CO_2 increased, in the middle of April it was 0.116 - 0.121%.

During the experiment, no regularities were revealed for the change in dry matter content depending on the treatments and storage period as well. The calculation of the natural loss of tubers mass to the end of storage period showed that the maximum mass decrease (2.07% from initial) was at the control, the least loss in mass was noted for treatment with “pills” salt filter, three hours - 1.53 %. Due to the fact that no significant decrease in dry matter content by the end of the storage period was observed, it can be assumed that the mass loss occurred on account of potato tubers respiration during storage period.

Various storage conditions have influenced the biochemical composition of the tubers. At the beginning of the experiment, the starch content was 12.15-13.05% (Table 1). During the entire storage period, its content in the control variant decreased to a minimum value of 8.98% in March, which can be explained by a air temperature decrease to minimum in the second decade of February (2.3°C). That was due to the fact that starch, when the temperature drops below + 4-5°C, transform into sugars. According data of Pshechenkov et al. (2007), it is possible to completely avoid the accumulation of sugars at a temperature of about 10°C.

Table 1. Starch content in potato tubers, %

Treatments		Analyses time				
	19.11.2020	28.12.2020.	21.01.2021.	02.03.2021.	31.03.2021.	28.04.2021.
Treatment 1 -control	13,05	12,79	11,33	10,21	8,98	12,18
Treatment 2	12,62	**12,40**	11,13	**11,53**	**10,71**	12,36
Treatment 3	12,98	12,70	**10,57**	**10,56**	**9,23**	12,19
Treatment 4	12,15	**10,03**	**10,86**	**11,07**	**10,39**	**11,75**
Treatment 5	12,38	**10,92**	11,17	**12,14**	**9,99**	**10,22**
Treatment 6	12,25	**11,6**	**10,12**	**10,63**	**11,05**	**10,34**
LSD_{05}	0,3	0,3	0,29	0,14	0,19	0,2

With the temperature rise from March to April (from 3.1 to 7.3°C), the starch content began to grow to a maximum value of 12.8% (sugars transform into starch at +5°C) In the studied variants, the starch content varied from month to month. In December, the starch content was significantly lower in the treatments with ozonizer (12.4%), "pills" salt filter, three hours (10.03%), filter with lumpy filling (10.92%), bulk surface of potassium salt (11.6%) compared to the control (12.79 %).
At the end of the storage period (April 28), the starch content was significantly lower in the last three variants: with the use of "pills salt filter, three hours - (11.75%), filter with lumpy filling (10.22%) and sylvinite bulk surface (10.34%) compared with the first treatments.
During the entire storage period, seed potato tubers were analyzed for the presence of phytopathogens. The data are shown in the Table 2.

Table 2. Phytopathogens determination during storage of potato tubers.

Treatments	Units	***Pseudomonas ssp.***	***Streptomyces scabies***	***Phoma foveata***	***Fusarium ssp.***	***Phytophtora infestans***
Treatment 1 - control	Infected tubers/ inspected tubers	24/50	33/50	5/50	10/50	13/50
	%	48	66	10	20	26
Treatment 2	Infected tubers/ inspected tubers	13/50	22/50	2/50	4/50	6/50
	%	26	44	**4**	**8**	**12**
Treatment 3	Infected tubers/ inspected tubers	11/50	21/50	3/50	6/50	7/50
	%	22	42	6	12	14
Treatment 4	Infected tubers/ inspected tubers	10/50	16/50	2/50	5/50	6/50
	%	20	**32**	**4**	10	**12**
Treatment 5	Infected tubers/ inspected tubers	8/50	16/50	3/50	6/50	8/50
	%	**16**	**32**	6	12	16
Treatment 6	Infected tubers/ inspected tubers	14/50	20/50	2/50	7/50	9/50
	%	28	40	**4**	14	18

Pseudomonas ssp., (48% of the infected tubers from the examined ones), *Streptomyces scabies* - 66%, *Phoma foveata* - 10%, *Fusarium ssp*.- 20%, *Phytophtora infestans* - 26%; were found at the control. That was the maximum number of infected tubers among all studied variants. The number of infected tubers was significantly less in all studied treatments.

The minimum percentage of tubers infected with *Pseudomonas ssp* was determined in treatment with aerosol generator and salt filter (lumpy filling) - 16%. The share of tubers infected by *Streptomyces scabies* was the smallest in variants with "pills" salt filter (three hours) and salt filter (lumpy filling) - 32%. The smallest number of tubers infected by *Phoma foveata* was observed in treatments with the ozonizer, "pills" salt filter (three hours) and the bulk surface of potassium salt - 4%.

The smallest number of tubers infected by *Phytophtora infestans* was noted for the treatment with the ozonizer and "pills" salt filter (three hours) - 12%. Thus, during the storage period, the minimum tubers damage by major diseases was noted in different treatments. In general,

treatments with using aerosol generator and "pills" salt filter (three hours) and salt filter (lumpy filling) appear to be the most promising with regard to suppression of potato pathogens during storage period.

CONCLUSION

Storing in air medium, contacting with natural sylvinite, is one of the most promising technologies in potato storage. Such environment has the ability to inhibit the growth of potato pathogens due to formation of light negative and saturation of air medium by saline aerosol. The smallest number of infected tubers was noted in the treatment with the use of aerosol generator blowing air through "pill"salt filter, three hours a day and in the variant with sylvinite bulk surface, the largest share of infected tubers was determined at the control.

The maximum natural loss of tubers mass to the end of storage period noted for the control variant (mass decrease 2.07% from initial), the least loss in mass was noted for treatment with "pills" salt filter, three hours - 1.53 %. No significant decrease in dry matter content by the end of the storage period was observed, so natural loss of tubers mass occurred on account of potato tubers respiration during storage period.

After additional studies in typical storages equipped with standard ventilation systems, a technology for potato storage, based on the creation favorable air environment saturated with negative air ions and saline aerosol, will be developed.

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