EFFECT OF MAGNETIC FIELD OF NEODYMIUM (NdFeB) MAGNET ON STORAGE QUALITY OF POTATOES

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Abstract. Modern techniques of potato tuber storage have a number of economic, technical, and technological disadvantages and they do not ensure high product safety – potato losses run up to 30 % per storage season. The work has been conducted on the effect of the magnetic field of neodymium (NdFeB) magnet on sprouting, weight loss and storage of potatoes, because this method is the most interesting and understudied. The equipment used in the research: equipment for magnetic potato treatment, NdFeB magnets, magnetometer to identify the positive and negative magnetic poles, and auxiliary instruments. As a result of the experimental studies it has been found that untreated potatoes had the weight loss of 39 %. The weight loss of potatoes treated with a positive magnetic field of 330…350 mT and time treatment 60…180 s was 4 %. The positive magnetic field of 330…350 mT was effective in suppressing sprout growth. It also inhibits the sprout growth in potatoes stored at 25°C. Potatoes receiving more than 330…350 mT dose were higher in the length of sprouts, and higher weight loss of potatoes (20…50 %). Also, potatoes receiving a negative magnetic field dose were higher in the length of sprouts, and higher weight loss (60 %) than those given a positive magnetic field dose. As a result of the experiments, the design of a new device for magnetic processing of potatoes has been developed. It is anticipated that magnetic fields influence the potato cells, as the result of the effects, potato tubers either lack in moisture, starch and other substances, or lose them quickly due to the inner-structure destruction.

Keywords: weight, potato, magnet, sprouts.

Introduction

Potato is the most important food crop in the Russian Federation after wheat. Basically, only one potato crop is grown in Russia per year, and the harvest is gathered from August through September. The reaped potato is preserved in refrigerators at a temperature of 8…10°C, and considering that at this temperature germination occurs, the chemical inhibitors are used to suppress it. Such methods of potato tuber storage have a number of economic, technical, and technological disadvantages and do not ensure high product safety, because potato losses run up to 30 % per storage season.

Quality and term of preservation of the potato are reduced due to loss of moisture, putrescence and physiologic damage. These deteriorations are directly coming from the temperature of storage, relative humidity, air circulation and the gas composition [1-4].

The method of forced blowing, use of chemical inhibitor agents, production of genetically modified (GMO) potatoes, which do not rot, are the main modern methods of storing potatoes. However, for various reasons, these methods have several disadvantages of an economic, technical and technological nature. For example, the method of forced blowing is the most energy-intensive, since during the entire storage period it requires a large number of sensors, electric motors, heating and cooling systems, which should work almost day-and-night. The European Commission cleared the way for the cultivation of GMO potato in the European Union in 2010, but only for industrial purposes, and not for food production. Besides, in Russia the cultivation of genetically engineered potato is prohibited.

There is information in science and technology about the influence of various physical methods on the processes occurring in agricultural industry [5-6].

The use of electrical, electromagnetic and magnetic effects and their various combinations with sound and optical effects makes it possible to adjust the functional state of biological objects of plant origin. For example, gamma-radiation has also been used for growth inhibition of sprouts in potatoes, and this has been proposed as an alternative to chemical sprout suppressants. These radiations interact with the substance of the product, including chemical changes, ionization and excitation, which modify the normal life process of biological cells. Ionizing radiation can kill bacteria, delay maturation, inhibit germination or disrupt the insect reproduction without heating or using chemical cultivation. At the same time, irradiation of potatoes and onions is more expensive procedure than treatment with chemical germination inhibitors, such as CIPC and MH [7-9].

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However, the effect of gamma-radiation is understudied, since gamma radiation can be accumulated in food and therefore harm the human health [10].

The objective of the present study was to work with the influence of the magnetic field of the neodymium (NdFeB) magnet on the sprouting, weight loss during storage and the internal structure of potatoes. The impact of the magnetic field of the neodymium (NdFeB) magnet on potatoes is understudied, besides it is also known that the magnetic field does not interfere with human health.

Materials and methods

"Aurora", "Ramona" and "Zhukovsky", the most popular potato cultivars trio used in the Stavropol region of the Russian Federation, were selected for the experimental studies. Magnetic processing was carried out using 2 types of neodymium magnets with different values of magnetic density, which for the first magnet was ± 330…350 mT and for the second magnet it was ± 430…450 mT. The magnetic potato treatment was 60, 180, 300, 600, 900 seconds. A magnetometer was used to identify the positive and negative magnetic poles of the permanent magnets. A microscope was used to examine slices of potato tubers pulp.

The device for magnetic impact on potatoes is a rectangular box, with permanent neodymium magnets laid on the bottom. According to the plan of the experiment, the potato tubers were placed on these magnets and exposed to impact of the magnetic field. Then the magnets were turned over to change the pole and the experiment was repeated.

The potatoes were treated by the magnetic field and stored for 20 days in bags at a temperature of 25°C and a humidity of 85 %. These values of temperature and humidity were selected in order to accelerate the processes of weight loss, the mouldering process, and sprouting in potato tubers.

In each variant of the experiment the weight of potatoes was 10 kg. The weight of untreated control potatoes was also measured. Loss of potato weight at the end of the experiment was determined by the formula (1):

$$\Delta = 100 - \frac{m_{END}}{m_{BEG}} \cdot 100 \text{, \%} \tag{1}$$

where m_{END} – weight of tubers at the end of the experiment, kg;
m_{BEG} – weight of tubers at the beginning of the experiment, kg.

Also in the course of the experiment the sprouting in potatoes was recorded and the length of the sprouts was measured.

For the statistical analysis the STATISTICA 12 program was used [11].

Results and discussion

As a result of the experimental studies it has been found that the magnetic treatment of potatoes affects the change in its weight during storage, at that the polarity of the magnetic field, the duration of treatment, and the magnitude of the magnetic field induction are important.

The loss of potato weight (formula (1)), measured on the 20th day of storage, showed that potato tubers treated with a positive magnetic field of 330…350 mT and a treatment time of 60…600 seconds do not exceed 12 percent, and the minimum value of the weight loss is 4 percent (Table 1).

Also, the sprout growth was not observed at the potato tubers treated with a positive magnetic field of 330…350 mT and treatment time of 60…600 seconds, while other variants showed sprouts appearance on tubers, and at the end of the experiment the length of the sprouts reached 20…30 mm.

Experimental studies in potato treatment with a negative magnetic field of neodymium (NdFeB) magnet show that the minimum weight loss of potatoes is 30 %, and the maximum weight loss reaches 60 %; also there are processes of rotting of tubers and an increase in the sprout growth. In the article these values have no practical use, therefore they are not presented in the form of tables or graphs.

According to the results of the experimental studies, the authors of the article propose a new device for magnetic processing of potatoes, which will reduce the loss of potatoes during storage. The main active element of the device is permanent neodymium magnets located in such a way that they can process potato tubers with their positive magnetic field. A schematic diagram of the operation of the device for magnetic processing of tubers is presented in Figure 1.

Table 1

Effect of a positive magnetic field on the weight loss of 3 potato cultivars

Magnetic signature, mT	**Processing time, seconds**	**Weight loss, %**
Aurora		
+ 330...350 mT	60	8
	180	4
	300	5
	600	9
	900	10
+ 430...450 mT	60	20
	180	18
	300	36
	600	47
	900	50
Untreated control	0	37
Ramona		
+ 330...350 mT	60	9
	180	5
	300	6
	600	10
	900	12
+ 430...450 mT	60	22
	180	20
	300	39
	600	50
	900	54
Untreated control	0	35
Zhukovsky		
+ 330...350 mT	60	7
	180	4
	300	10
	600	12
	900	15
+ 430...450 mT	60	25
	180	30
	300	37
	600	49
	900	55
Untreated control	0	39

Processing of tubers in this device improves the ability of potato to be stored for a long time without significant weight loss, prevents damage from microbiological and physiological diseases, prevents deterioration of commodity, food and seed qualities, increases resistance to diseases and mechanical damage.

Studies on the magnetic fields effect on plants, fruit and vegetables have proved their positive impact, however, at the moment, there is no clear theoretical basis, allowing us to finalize the mechanism of the magnetic fields effect. Some scientists have linked changes in the plants with the influence of the magnetic field on the water contained in them.

Permanent magnets 1 are inside a moving conveyor belt 2, on which potato tubers 3 are located. Potato tubers are affected by a magnetic flux Φ. If the potato tuber 3 appears between the magnets in the gap *a*, it is affected by the magnetic flux Ф1 and Ф2 of the nearby magnets, which directions and values are summed up that does not reduce the effectiveness of magnetic treatment. The speed of the conveyor belt is chosen in such a way that the processing time of potatoes is 60…600 seconds. Potato treated with a permanent magnet field is sent to storage for long-term preservation.

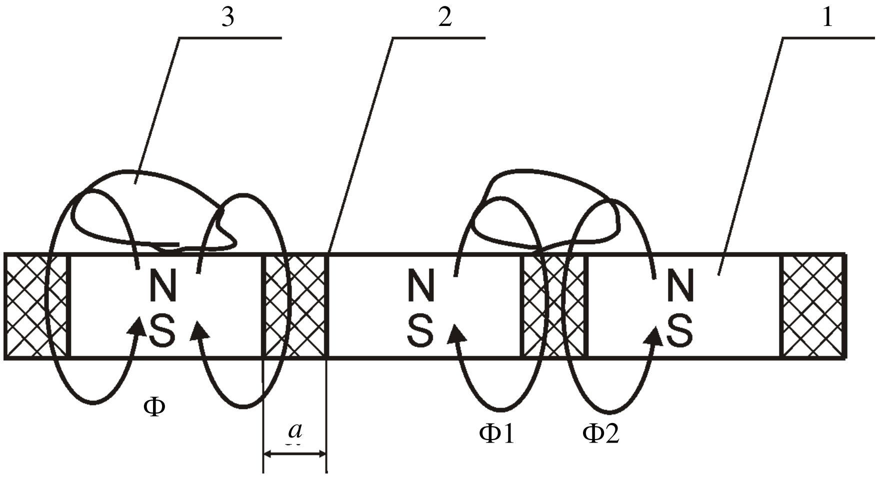

Fig. 1. **Principle of operation of device for magnetic processing of potato tubers:** 1 – neodymium magnet; 2 – belt; 3 – potato tubers; Ф, Ф1, Ф2 – magnetic fluxes; *a* – gap between the magnets

A number of hypotheses were developed; they can be divided into the following three groups:

1. The first, combining most of the hypothesis implies that magnetic fields effect on the salt ions presented in water; under the influence of a magnetic field the polarization of ions and their deformation take place; it increases the probability of their convergence and ultimately nucleus formation;
2. The second group implies that magnetic fields effect on the water impurities, which are in the colloidal state;
3. The third group includes ideas about the possible impact of magnetic fields on the water structure. This effect, on the one hand, can cause changes in the aggregation of water molecules, on the other – disrupt the orientation of nuclear spins in the hydrogen molecules.

To confirm or refuse the hypotheses mentioned above, as well as for development of our own scientific hypothesis, we made some slices of potato tubers pulp and examined them under a microscope at the same magnification power. The slices were made before treatment and after the end of the experiment. The structure was studied under magnification 5X and 10X. Comparisons were made for untreated potato tubers, tubers with minimum and maximal mass losses.

At the end of the experiment it was found that magnetic exposure leads to structured changes in potato tubers resulting in changes of starch salts and moisture particle concentration and size. The experimental tubers with minimal mass loss demonstrated increase in their size and moisture particle concentration (Fig. 2c, 2d) in comparison with the untreated control tubers (Fig. 2a, 2b).

The experimental potato tubers with maximum mass loss demonstrated disintegration of the internal structure, which is difficult to see at the experimental magnification (Fig. 2e, 2f). It is evident that exposure to the magnetic fields destroyed internal moisture particles at the cellular level, resulting in acceleration of the moisture evaporation process and the mass loss process. Damaged and cut tubers confirmed these results. Potatoes treated with a magnetic field within the range from + 330 to + 350 mT and processing time within the range from 60 to 600 seconds formed protective layers more quickly than at other doses of magnetic treatment, resulting in reduction of tuber mass losses. At other doses of magnetic exposure protective layers practically were not formed and the tubers dried up.

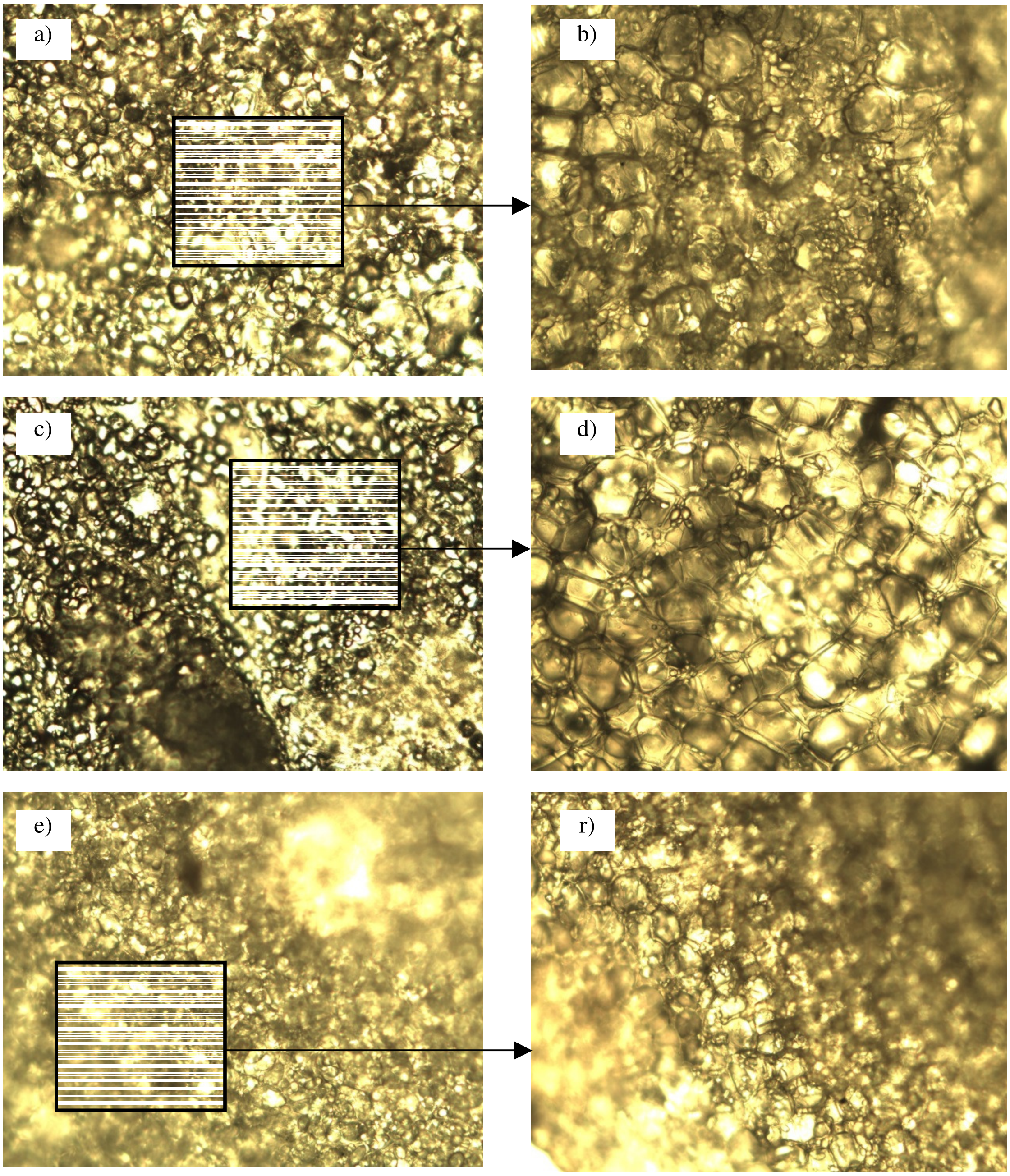

Fig. 2. **Structure of starch and moisture particles in potato tubers at the end of experiment:** a – untreated control, 5X magnification; b – untreated control, 10X magnification; c – tuber with minimal losses, 5X magnification; d – tuber with minimal losses, 10X magnification; e – tuber with maximum losses, 5X magnification; f – tuber with maximum losses, 10X magnification

Conclusions

1. In the process of the experimental studies on the treatment of potato tubers with a permanent magnet field it was found that magnetic treatment affects the preservation of the weight of potatoes during storage, at that the polarity and duration of treatment has a significant value.
2. The time range, in which the magnetic treatment is effective and prevents loss of the weight of potatoes, is bigger at the positive magnetic field; consequently, at the manufacture of a device with permanent magnets for treatment of potatoes it is necessary to select the configuration and placement of the magnets so that to carry out the processing of potatoes with the positive magnetic field.

3. As a result of the experimental studies it has been found that untreated potatoes had the weight loss of 39 %.
4. Weight loss of potatoes treated with a positive magnetic field of 330…350 mT and treatment time 60…180 s was 4 %.
5. Potatoes receiving more than 330…350 mT dose were higher in the length of sprouts and higher weight loss of potatoes (20…50 %).
6. Also, potatoes receiving a negative magnetic field dose were higher in the length of sprouts and higher weight loss (60 %) than those given a positive magnetic field dose.
7. It is anticipated that magnetic fields influence the potato cells, as the result of the effects potato tubers either lack in moisture, starch and other substances, or lose them quickly due to the inner-structure destruction.

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