Resource-saving technologies in storage and processing of agricultural products

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Abstract. Over the past years, there has been an intensive development of interactive technologies that make it possible to intensify the operational processes of cleaning, transportation, purification from impurities, drying and storage of various products. The agriculture of Russia, as an integral part of the agro-industrial complex, shall be able to use broadband, mobile LPWAN communications, information technologies (Big Data, artificial intelligence, control platforms), radio frequency tags, controllers, sensors, domestic instrumentation controls to significantly increase the efficiency. The potential for modernization of the industry is quite huge. The development and improvement of working bodies make it possible to create machines and working bodies for work in difficult climatic conditions. However, it is quite difficult to set up machines to work within specific climatic conditions, which often limits the effectiveness of the application of innovative developments in different regions of the Russian Federation.

1 Introduction

In terms of agricultural land, the Russian Federation ranks third in the world (it stays behind the United States and India), and in terms of such significant indicators as output per worker, productivity and other indicators, it lags far behind countries with developed agriculture. The development of agriculture in Russia in recent years, in the context of an embargo on the import of a number of products, has identified some industry problems that need to be addressed, including through the introduction of digital technologies. Currently, Russian agriculture is at a low digital level of development. It is possible to increase production

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volumes and reduce losses of agricultural products during harvesting, storage and processing through the effective implementation and proper application of digital smart technologies [1].

2 Problem statement

The relevance of ensuring the country's food security and the development of export potential require the transformation of agriculture into a high-tech industry that can provide food not only for itself, but also for many countries of the world. It is necessary to create opportunities for the introduction of innovative developments, to stimulate the adoption of advanced management decisions that can provide the population of Russia with high-quality and safe products.

Decree of the President of Russia No. 204 dated May 7, 2018 "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" set the task of transforming priority sectors of the economy and the social sphere, including agriculture, through the introduction of digital technologies and platform solutions [1,2].

The purpose of the study is to evaluate new energy-saving technologies for the storage and processing of agricultural products.

3 Research questions

Agriculture is one of the leading sectors of the economy of the Russian Federation, which ensures the food and economic security of the country [3], as well as the labour potential of rural areas [4]. As it is known, the competitiveness and profitability of agricultural production is determined by its resource and energy intensity and the volume of direct and indirect costs. In recent years, there has been an annual increase in such costs due to the multi-operational nature of agricultural technologies, rising prices for energy carriers, agricultural machinery, mineral fertilizers, plant protection products at low prices for manufactured products [5]. Under the current conditions, the main opportunity to increase the profitability of agricultural production is the development and implementation of modern resource-saving agricultural technologies [6,14].

4 Materials and methods

It is considered necessary to carry out the digitalization of agriculture at the global level in order to bring the industry to a high-tech level.

The names of digital smart technologies that can be used in agriculture are shown in Table 1 [1].

All considered digital technologies will fully automate all agricultural processes through the use of computer systems and the Internet. The digitalization of the agro-industrial complex will make it possible to carry out qualitatively and timely processing of daily data arrays coming from sensors installed in fields, on farms, machinery, warehouses. The processing of all incoming data will make it possible to analyze ongoing changes, identify patterns, and thereby increase the efficiency and sustainability of agricultural development as a whole.

Table 1. Digital smart technologies for processing and storage of agricultural products.

Name	Features	Application range
Internet of Things–IoT	A system for exchange of information between different devices, equipment and machines, which allows to fully automate processes in agriculture	"Smart" farms and greenhouses; raw material management; storage of agricultural products
Big Data	Structuring the huge amounts of various data and information through software tools	Processing of agricultural products
"Smart" storage	They allow to monitor the state of products during storage due to algorithms that are specially defined in online mode. It helps to make the right decisions and eliminate violations of the established parameters	Storage of agricultural products

5 Results

Effective innovative technologies for the production, storage and processing of agricultural products are presented by the developer - All-Russian Research Institute of the Meat Industry named after V.M. Gorbatov.

Resource-saving technology for the production of carbohydrate-protein stabilizers. The meat industry produces more than 5,000 products using soy-protein products: boiled, semi-smoked and boiled-smoked sausages; beef and pork products, semi-products, canned products, baby food products, etc. The volume of soy protein products purchased by Russia is about 10% of the world volume. These products are used as a substitute for meat raw materials. The economic effect from the use of StUB (soy protein) instead of meat raw materials per 1 ton of products is 12-17 thousand rubbles in terms of receipts of boiled and semi-smoked sausages, 15-21 thousand rubbles in terms of pates, and up to 14 thousand rubbles in terms of semi-products [7].

Complex bacterial preparations for the intensification of the production of meat products - PB MP (bacterial preparation for meat products) and PBK RB (complex bacterial preparation for meat products) fertilizers are various combinations of sublimated concentrates of living cells based on producers of lactic acid bacteria and denitrifying microorganisms. They are used in the production of 112 raw smoked and dry-cured sausages at the rate of 1-2 activity units per 100 kg of raw materials in order to intensify the operational process and improve the quality of the finished product. They allow to accelerate the operational process of production of raw smoked and dry-cured meat products, obtaining high-quality meat products, increasing the utilization rate of climatic chambers and thereby reducing energy costs by 2-25%. For meat industry enterprises the economic effect of the introduction of bacterial fertilizers into the production of sausages is 20-40 rubbles/kg of the semi-product [7].

Resource-saving technology for the production of extruded products using meat components. The technology for production of extruded dry products using native meat components in an amount of up to 20% makes it possible to involve in processing not only muscle tissue, but also connective tissue waste from meat production. Finished dry porous products are distinguished by a high content of animal protein (8-15%), low fat content (0.3-0.7%) and meet the safety requirements for food products of this type (corn sticks, snacks). Operational modes for the production of vegetable and meat extrudates using various vegetable components (flour, grains of various crops, including legumes with a high content of vegetable protein) have been developed. The economic effect is 3-4 thousand rubbles per

1 ton of finished product. For enterprises that manufacture the food additives, for manufacturers and enterprises of the food concentrate industry, meat processing enterprises in Russia [7].

The developer - Volgograd Research and Engineering Institute of meat and dairy cattle breeding and processing of livestock products also offers the following technical solutions:

- Rational technologies for the production of livestock products and dietary supplements enriched with organic selenium. The inclusion of preparations enriched with organic selenium in the diet of lactating cows contributed to better digestion of essential nutrients, an increase in milk yield by 4.7%, fat content in milk by 0.17%, and an improvement in the quality composition of milk. The use of supplementary feedings with organic selenium in the production of beef contributed to an increase in the palatability of hay by 6.7-9.9%, haylage by 3.4-5.9%, an increase in the average daily growth of bulls by 13.3%, pulp yield by 5.9%, in the production of pork, to improve meat productivity and the qualitative composition of the pulp of gilt carcasses, the content of selenium in meat, as well as to increase egg laying in laying hens by 9.8%. The economic effect from the introduction of preparations and feedings enriched with organic selenium is over 120 million rubbles [7].
- Technology for the use of chickpeas and products of its modification in the production of food and feed products of increased biological value provides a full-fledged replacement for soy, and in a number of features it even surpasses the soy. Chickpea contains up to 32% of protein, up to 8% of fat, 48-60% of carbohydrates, 28.5 mcg/kg of selenium. New formulations of pure milk substitutes based on chickpeas have been developed. They contribute to an increase in the average daily gain in live weight of young animals by 5.1% and a decrease in the cost of growth by 5.6%. Methods for livestock and poultry feeding have been developed and patented. A series of new food products enriched with selenium through the use of chickpeas (mayonnaise, sausages, protein product, meat products filled with chickpeas, chickpea milk, dietary supplements, confectionery) has been developed. The economic effect from the introduction of developments in animal breeding and processing industry is over 200 million rubles per year.

6 Findings

Developer: Russian Research and Development Institute of Butter and Cheese Production:

- resource-saving butter production technology. New technologies have been developed for a number of varieties of low-fat butter: with a traditional flavour bouquet - "Edelweiss" and "Clean Field", with an original flavour bouquet - a snack butter (with vegetables, herbs or their mix). Process flow diagrams provide for the use of natural or recombined cream as the main raw material. Structure stabilizers, vitamins, dyes and flavours, natural vegetable additives and herbs are used as additional components. The effectiveness of 116 technologies lies in the possibility of increasing the volume of butter production by 25-30% from the same resources of raw milk, reducing the cost by 20-30%. Widespread development of new technologies is of great social importance, as it makes it possible to provide the country's population with low-fat oils that more fully meet the requirements of a healthy diet. For Russian dairy industry enterprises [7];
- intensive technology of manufacturing of semi-hard cheeses with a low temperature of the second heating ("Gollandskiy SNTS", "Kostromskoy SNTS", Poshekhonsky SNTS), the implementation of which allows to reduce the ripening time by 1.5-2.5 times, ensures high quality of cheeses, increases the cheese yield by 5 -7%, reduces labour and energy costs by 15-20% and obtains a finished product with nutritional

and organoleptic characteristics close to traditional cheeses of the same name. Intensive technology is based on the use of a complex of biotechnological factors with the participation of bacterial starter cultures of increased autolytic action. For joint stock companies and state cheese factories in Russia [7].

Developer: Russian Research and Development Institute of Dairy Industry:

- new modern types of technological equipment for the dairy industry. There are over 2,000 dairy enterprises in Russia. The creation of domestic equipment that allows to develop the new high-quality multicomponent products based on milk and to replace equipment purchased abroad is an important task. For the first time in Russia, Russian Scientific Research Institute of Dairy Industry has launched industrial production of the following types of certified equipment: GURT-300/160 hydrodynamic rotary unit for the production of fluid multicomponent products of various densities and viscosities; IS-40 and IS-250 grinders-mixers for the production of pasty products; TSV-0.84 and TSV-0.36 vertical scraper heat exchangers for heat treatment of liquid-viscous food products; UIP-0.25 device for measuring the bulk density of milk. The economic effect at enterprises operating new equipment is formed by increasing of labour productivity, expanding the range of products, reducing losses, etc. The annual national economic effect is about 2 million rubles. For enterprises of dairy and other industries [7];
- resource-saving technology of ultrafiltration fractionation of milk raw materials in the production of dairy products is a technology of pasty dairy products based on ultrafiltration of sour milk. The technological regulation allows to organize a continuous automated operational process in order to obtain the fermented pasty products (with a mass fraction of solids of 15-23%), to use food ingredients and dairy raw materials effectively, and to obtain a finished product with high sanitary and hygienic indicators and good taste. In the production of curd products, the consumption of raw materials is reduced by 10-15%, as a result the economic effect will be 3.5-5 thousand rubbles/t. Secondary raw materials - ultrafiltrate (whey) can be effectively used as a raw material for the production of lactose and for obtaining the drinks with high nutritional and biological value. For dairy industry enterprises [7].

7 Discussion

An innovative direction in the storage of agricultural products is the introduction of storage technology using a controlled gas environment [8,9].

Each method of storage of agricultural products in a controlled gas environment has its own advantages and disadvantages.

A method of storage of biological objects in a controlled gas environment (patent No. 2007902, RF) [10] provides placing a biological object in a chamber, chamber sealing, determination of the biological object respiration intensity, creation of a gaseous medium of a given composition by purging the chamber and maintaining a given concentration of oxygen and carbon dioxide by purging. Before placing a biological object in the chamber, the composition of the gaseous medium and the frequency of the chamber purging are determined for each type of biological object. The purging frequency is determined depending on the intensity of the biological object respiration, and the purging is carried out discretely in time that is set depending on the purge frequency [11,12].

The main disadvantage of this storage method is the need to constantly create a gaseous medium of a special composition and its high consumption, resulting from the need to be forced out of the container after a certain period of time as unusable. The period of mandatory change of the gaseous medium in the container is determined by the type and variety of fruit

and vegetable products, the tightness of the container and the storage temperature and varies from 3 to 30 days.

The method for adjustment of the gaseous environment during the storage of fruit and vegetable products (patent No. 2102860, RF) [11] is based on the removal of carbon dioxide from the container. In order to do it, the container with fruit and vegetable products is blown until air is completely displaced from it with a nitrogen-oxygen mixture with an oxygen concentration of not more than 13%, then the container is closed. During the storage of fruit and vegetable products, control is carried out using an oxygen content sensor in the container. When oxygen content reaches the value of less than the gas mixture is pumped out of the container. The disadvantage of this storage method is the use of expensive containers for storage of fruits and vegetables in a controlled gas environment and the complexity of regulating the composition of the gas environment [13].

In order to reduce storage losses in the method of storage of biological objects in a controlled gas environment (patent No. 2016501, RF) [12] that includes the loading of the chamber, chamber sealing, creation of a gas environment of a given composition, control of the content of oxygen and carbon dioxide in the chamber and maintenance of their specified concentration, purging with nitrogen, before loading the chamber, the respiration coefficient of a biological object is determined depending on the concentration of O2 and CO2 in the chamber and the initial optimal content of oxygen and carbon dioxide is set depending on the biological object respiration coefficient, and also the content of oxygen and carbon dioxide during storage is set. To achieve a positive effect during storage, it is necessary that to regulate the composition of the gaseous medium in the chambers promptly. It is possible only when a technically created gaseous medium is used (for example, using nitrogen or a gas mixture of nitrogen and oxygen from gas separation apparatuses (cryogenic plants, BARS, etc.)). The process of air separation and obtaining the necessary gaseous medium in this case is automated and controlled [14,15]. The disadvantage of this storage method is the use of expensive sealed chambers for storage of products in a controlled gas environment and significant operating costs associated with the cost of instrumentation.

8 Conclusion

The analysis of scientific developments and commercial proposals of leading manufacturers of agro-industrial equipment has shown that the introduction of operational process control systems into production is being actively carried out. For convenience, these systems can be divided into two groups. The first, and the most common, control systems consist of one or more sensors that allow (for example) to control the position of the unit or the entire working body for the possibility of further adjustment (automatic system for copying the soil landscape, control system for returning grain to final threshing and electric adjustment of sieves on the combine ACROS 595 Plus). More complex systems allow to carry out automatic change of grain harvester operational mode depending on the received data. For example, the CLAASLEXION combine harvester has an automatic mass flow control system that allows to adjust the speed of the combine with an increase in the difference in the speed of the engine and rotors. The disadvantage of such systems is the high cost or the inability to carry out the full control of the harvesting process. The second control systems allow to use video cameras to visualize the work of the working bodies of the combiner on the computer display. However, the high cost of this system and the inability to carry out the quick adjustment of the working bodies significantly affect the amount of losses and the purity of the crop [16]. Article is prepared with support of the Ministry of Education and Science of the Russian Federation, amendment No.075-02-2020-1529/1 dated 21.04.2020.

References

1. T. G. Pavlenko, *Resource-saving technologies in storage and processing of agricultural products* (Kartush publishing house, Orel, 2021), 49-52
2. Decree of the President of Russia No. 204 dated May 7, 2018 "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024" (2018)
3. Z. A. Voitleva, Periodical of the Ural State Economic University **5(37)**, 177-181 (2011)
4. S. Rajabi, M. Maresca, A. V. Yumashev, R. Choopani, H. Hajimehdipoor, Cancer Therapy Biomolecules **11(4)**, 534 (2021). https//doi.org/10.3390/biom11040534
5. A. P. Zinchenko, Agrarian periodical of Ural **2**, 18-23 (2008)
6. A. V. Gostev, I. G. Pykhtin, L. B. Nitchenko, V. A. Plotnikov, N. P. Gaponova, *Theoretical foundations for the effective application of modern resource-saving technologies for the cultivation of grain crops* (Federal State Budget Scientific Institution Russian Research Institute of Agriculture and Soil Protection from Erosion, Kursk, 2016)
7. A. P. Ogarkov, S. A. Ogarkov, S. V. Koteev, *Science-intensive effective innovative technologies for the production, storage and processing of agricultural products (Technologies summary)* (Russian Institute of Agrarian Problems and Informatics named after A.A. Nikonov, Moscow, 2014)
8. S. N. Afinogenova, *Analytical review of the state of storage of potatoes in the storage facilities of the Ryazan region In "Innovative approaches to the development of the agro-industrial complex of the region" collection of papers: Materials of the 67Th international research-to-practice conference* (Publishing house of the Ryazan State Agrotechnological University, Ryazan, 2020), **Part 1**, 21-25
9. E. Lavrov, N. Pasko, O. Siryk, O. Burov, M. Natalia, IEEE 15th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET) 179-184 (2020). https//doi.org/10.1109/TCSET49122.2020.235418
10. R. A. Vinokurov, S. F. Dergunov, V. A. Turtushov, Patent RF № 2518782 (2014)
11. A. I. Boyko, I. A. Uspensky, S. N. Borychev, *Potatoes harvesting using interactive technology Collection of papers: Innovative approaches to the development of the agro-industrial complex of the region: Materials of the 66th international research-to-practice conference* (Ryazan: Ryazan State Agrotechnological University, 2015), 38-40
12. P. Skrypchuk, V. Zhukovskyy, H. Shpak, N. Zhukovska, H. Krupko, Journal of Ecological Engineering **21(6)**, 42-52 (2020)
13. R. V. Beznosyuk et al., *Resource-saving grain production technology using an interactive control system Materials of the 68th international research-to-practice conference "Principles and technologies of introduction of environmental science into production in agriculture, forestry and fisheries."* (Publishing house of the Ryazan State Agrotechnological University, Ryazan, 2017), **Part 1**, 29-33
14. A. L. Zolkin, A. G. Burda, Yu. M. Avdeev, D. I. Fakhertdinova, IOP Conference Series: Earth and Environmental Science **677**, 032092 (2021). https//doi.org/10.1088/1755-1315/677/3/032092
15. N. H. Noraliev, F. E. Yusupova, Digital technologies in agricultural industry Scientific and educational issues **8(92)**, 4-10 (2020)

16. Yu. A. Dmitriev, M. A. Chirkov, M. S. Chistyakov, X International Scientific and Practical Conference "Regions of Russia: Strategies and Mechanisms for Modernization, Innovative and Technological Development" **14(2)**, 809-811 (2019)