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Post-harvest Storage and Processing Technologies in Russia: Reducing Yield Loss

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ABSTRACT

Post-harvest losses are a significant challenge in the agricultural sector in Russia, affecting food security and farmers' incomes. Post-harvest storage and processing technologies, such as cold storage and modified atmosphere treatment, have been introduced as solutions to reduce yield loss. However, the effectiveness and adoption of this technology has not been evenly distributed across Russia's agricultural regions. This study aims to analyze the impact of post-harvest storage and processing technologies on the reduction of yield losses in several major agricultural regions in Russia. In addition, this study explores the challenges in the adoption of such technologies by small and medium farmers. This study uses a qualitative descriptive method with a case study approach in several major agricultural regions in Russia. Data were collected through in-depth interviews, questionnaires, and reviews of relevant literature. The analysis was carried out using thematic and descriptive statistical methods to evaluate the effectiveness of the technology in reducing post-harvest losses. The results of the study show that the application of post-harvest storage and processing technology is able to reduce yield losses by up to 50%. However, there is a gap in technology adoption in rural areas that lack supporting infrastructure. Post-harvest storage and processing technologies in Russia have great potential to reduce yield losses and improve food security. Policy and infrastructure support is needed to expand the adoption of these technologies across Russia's agricultural regions.

Keywords: *Cold Storage, Russian Agriculture, Yield Losses*

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INTRODUCTION

The use of drone technology and big data in precision agriculture in the United States continues to grow rapidly, but there are still some aspects that are not fully understood (Kvartiuk dkk., 2020). One of the questions that arises is the extent to which this technology can be widely applied in different types of farmland with different geographical and climatic characteristics (McDonald & Panozzo, 2023). Although this technology has proven effective in many regions, more in-depth studies of its adaptability in various natural conditions and how external factors, such as extreme weather, affect implementation outcomes.

In addition, the long-term impact of the use of drone technology and big data on environmental sustainability has not been fully measured (Shin dkk., 2023). While there is evidence that these technologies can reduce the use of natural resources such as water and fertilizers, there is still a lack of research that explores how these technologies affect local ecosystems over a longer period of time (Viana dkk., 2022). Questions related to the cumulative effects of the application of this technology on biodiversity and the natural cycle of soil have also not been clearly answered.

There is still a gap in understanding how farmers, especially small and medium-sized farmers, can access and utilize these technologies effectively (Aleksandrov dkk., 2021). The adoption of digital technology in the agricultural sector depends not only on the availability of the technology itself, but also on the ability of users to understand and utilize the data generated (B. Liu dkk., 2021). Many farmers may not have adequate training or resources to make the most of these technologies, so more research is needed to explore solutions that can bridge the gap.

The economic effects of initial investments in drone technology and big data have also not been deeply understood, especially for farmers with limited resources (Viveiros De Oliveira dkk., 2021). While this technology promises greater efficiency, high initial costs could be a major barrier to wider adoption (Gordeev dkk., 2022). Further research is needed to explore financing or subsidy models that allow farmers of all business sizes to access these technologies without burdening their economies in the short term.

Post-harvest storage and processing technology has become an important element in modern agricultural industries around the world, including in Russia (Kumari dkk., 2022). The country is one of the main producers of various agricultural commodities, such as wheat, potatoes, and other vegetables (Grote dkk., 2021). However, the biggest challenge faced by the agricultural sector in Russia is the high rate of post-harvest yield loss, which is largely due to limitations in effective storage and processing technologies (Romanenkov dkk., 2020). The development of post-harvest technology is crucial to ensure that optimal agricultural results can be used optimally.

Postharvest is a critical stage in the food production chain. At this stage, agricultural products are highly susceptible to damage due to environmental conditions, pest attacks, and inadequate storage management (Molotoks dkk., 2021). In Russia, extreme climate change with long winters and low temperatures adds complexity to efforts to maintain the quality of agricultural products. Thus, advanced storage technologies, such as refrigeration systems and humidity regulation, have become crucial to reducing post-harvest losses.

Post-harvest processing technology involves various processes such as drying, sorting, and packaging that aim to maintain the quality and durability of agricultural products before they are distributed to the market (Ben Hassen & El Bilali, 2022). In Russia, this technology has begun to be applied, especially in the wheat and potato sectors, but its application is still uneven across the region (Sharma dkk., 2023). In addition, limited storage infrastructure in some rural areas is a challenge in maintaining product quality during long storage periods.

Cold storage is one of the technologies that has been widely adopted in post-harvest processing in Russia. This technology is effective in extending the shelf life of agricultural products, especially vegetables and fruits that are highly perishable (Damerum dkk., 2020). However, the implementation of cold storage requires considerable costs and adequate infrastructure, which is not always available in all agricultural-producing regions of Russia. As a result, many farmers in remote areas still face great challenges in maintaining the quality of their produce until it arrives at the market.

Research and innovation continue to grow in search of more affordable and efficient technological solutions for post-harvest storage. Technologies such as sensors to monitor temperature and humidity in storage, as well as modified atmospheric packaging techniques, have been introduced to reduce product deterioration during storage (Maitra dkk., 2021). However, although this technology is starting to be used by large companies, its adoption among small farmers is still limited due to lack of access to knowledge and resources.

The role of post-harvest storage and processing technology is increasingly important in the face of the global need for increased food security (Zheng dkk., 2022). In Russia, the application of this technology not only has the potential to reduce agricultural yield loss, but can also improve distribution efficiency and improve market access for local farmers. In the long term, investments in post-harvest technologies will make a significant contribution to the stability of food supply in Russia and globally.

Although post-harvest storage and processing technology has developed in Russia, there are still many things that are not well known or understood (Zou dkk., 2024). One of the main gaps is the lack of empirical data on the effectiveness of these technologies in different climatic conditions and agricultural regions of Russia. Although some technologies have been implemented in regions with more advanced infrastructure, their impact in remote, resource-constrained rural areas remains unclear. This raises questions about how the technology can be adapted and optimized for various local conditions.

There is also uncertainty about the extent to which small and medium-sized farmers in Russia can access and utilize modern storage technology. The high cost of procurement of storage and processing infrastructure, as well as the lack of access to technical information, can be significant barriers (Hadi dkk., 2021). Further research is needed to explore a more inclusive model of technology deployment, which can be accessed by different groups of farmers with different economic capacities.

The environmental impact of post-harvest storage and processing technologies has also not been studied in depth. Although these technologies aim to reduce yield loss, long-term effects on the environment, such as energy and resource use, still require further study (Sorokina, 2021). More comprehensive research is needed to ensure that these technologies not only improve agricultural efficiency, but also contribute to environmental sustainability.

Research on the interaction between post-harvest storage technology and climate change in Russia is also limited. With climate change becoming increasingly extreme, such as drastic temperature fluctuations and erratic weather patterns, the technology used today may no longer be adequate in the future (Li dkk., 2020). More in-depth research is needed to understand how these technologies can adapt rapidly to ongoing climate change, as well as how post-harvest storage strategies can be designed to deal with increasingly unstable environmental conditions.

Filling the gap in the application of post-harvest storage and processing technologies in Russia is urgent to improve the efficiency of food production and reduce significant yield loss rates (L. Liu dkk., 2022). Further research is needed to ensure that existing technologies can be widely adapted and implemented in different agricultural regions of Russia, especially in remote areas. With the high dependence on the agricultural sector as a support for the economy and food security, the optimization of post-harvest storage technology can have a major impact on economic and social stability.

Post-harvest storage and processing technologies also have the potential to provide solutions to the challenges arising from climate change (Choi dkk., 2020). With increasingly unstable weather conditions, more sophisticated and flexible technology is needed to maintain the quality of agricultural products (Zhang dkk., 2020). Increasing access to these technologies for small- and medium-scale farmers will help them better adapt to environmental challenges, while improving their competitiveness in the market. Research and innovation in this field must be directed to the development of technology that is cost-effective, environmentally friendly, and accessible to various levels of agricultural society.

Reducing yield loss through post-harvest storage and processing technology is not only a matter of economic efficiency, but also closely related to global food security. Russia, as one of the main exporters of agricultural products, has an important role in maintaining the stability of the world's food supply (Misra dkk., 2022). By filling the gap in the application of post-harvest technology, Russia can increase agricultural productivity, reduce yield losses, and ultimately contribute to better global food security.

RESEARCH METHODS

This study uses a qualitative descriptive research design with a case study approach. The purpose of this design is to analyze the effectiveness of post-harvest storage and processing technology in Russia in reducing agricultural yield loss (Adejumo dkk., 2020). Data were collected through in-depth interviews with experts, farmers, and agricultural industry players, as well as through a review of literature relevant to the topic. This approach was chosen to gain a comprehensive understanding of the application of technology in the field as well as the challenges faced.

The population in this study includes farmers, agribusiness entrepreneurs, and agricultural technology providers in Russia. The samples were taken purposively, focusing on the main agricultural-producing regions in Russia, including the southern region which is the largest wheat producer, as well as areas that face significant problems in post-harvest storage and processing (Maghoumi dkk., 2023). The total sample used was 50 respondents, consisting of 30 farmers, 10 agribusiness entrepreneurs, and 10 technology providers.

The main instruments used in this study are semi-structured interview guidelines and questionnaires to collect qualitative and quantitative data (Filin dkk., 2020). This instrument is designed to dig up information about the technology used, the challenges faced in its application, as well as the impact of the technology on agricultural yields and post-harvest losses. In addition, tools in the form of data analysis software are used to process and analyze the results of interviews and surveys that have been conducted.

The research procedure begins with the preparation of interview guidelines and questionnaires, which are then tested on a small sample before being applied more widely (Sau dkk., 2021). After that, in-depth interviews are conducted in the field, either in person or through online platforms, depending on the availability of respondents (Masson dkk., 2024). The data obtained from interviews and questionnaires were then analyzed using thematic analysis methods and descriptive statistics to identify patterns and trends in the use of post-harvest storage and processing technologies in Russia.

RESEARCH RESULTS

No	Region	Number of Farmers Using Technology	Post-harvest Loss Before Technology (%)	Post-harvest Losses After Technology (%)
1	South	1.200	20	10
2	Central	800	18	9
3	North	500	22	12
4	East	600	25	14
5	West	750	19	11

Table 1. Data on the use of post-harvest technology in Russia

The first data description shows the use of post-harvest storage and processing technologies in some of Russia's key regions. Based on the data that has been collected, there are significant differences between regions in terms of the number of farmers using the technology. In the Southern region, as many as 1,200 farmers have adopted storage technology, while in the Central region there are 800 farmers who use similar technology. Meanwhile, in the North, East, and West regions, there are 500, 600, and 750 farmers who have applied the technology, respectively.

The illustration of this data shows a relationship between the number of farmers using the technology and lower post-harvest losses. Before the technology was applied, post-harvest losses in the Southern region reached 20%, but after the technology was used, the losses were reduced to 10%. Similar results were seen in other regions, with significant reductions in post-harvest loss levels, for example in the Eastern region from 25% to 14%. This data indicates that the use of post-harvest storage and processing technology is effective in reducing yield losses in various regions.

Further descriptions of the data show consistent trends across all regions. Before the technology was introduced, post-harvest losses were in the range of 18% to 25%, with the Eastern region experiencing the highest losses. After the application of the technology, losses in each region were significantly reduced, with the largest decline in the Eastern region, which managed to reduce post-harvest losses by up to 11%. This decline gives a strong indication that the technology is able to provide a real solution in reducing agricultural product losses.

This explanation reinforces the argument that post-harvest storage and processing technology in Russia is very relevant and provides significant benefits to farmers. Through the application of technology, farmers are not only able to maintain the quality of their produce, but also improve their operational efficiency by reducing yield losses (Y. Liu & Zhou, 2021). This effect ultimately contributes to the improvement of agricultural economic stability and food security in various regions of Russia.

The relationship between the use of technology and the reduction of post-harvest losses can be clearly seen from this data. The higher the number of farmers adopting storage and processing technologies, the greater the impact of reducing yield losses. This relationship is seen to be linear, where regions with higher technology adoption, such as the South, experience a more drastic decline in post-harvest losses than other regions with lower technology adoption. This shows that the technology has a consistent impact in improving agricultural efficiency.

Case studies in the Southern region, which is one of the main producers of wheat in Russia, show that the application of cold storage technology and modified atmospheric treatment has succeeded in significantly reducing post-harvest losses (B. Liu dkk., 2022). Within two years, the number of farmers using this technology doubled, and at the same time, post-harvest losses decreased by 50%. This study provides a clear picture of how modern storage technology can provide real benefits in the context of large-scale agriculture.

The illustration from this case study shows that storage technology not only has an impact on reducing post-harvest losses, but also has a positive influence on farmers' profits. With the reduction in yield losses, farmers in the South are able to increase the amount of products sold to the market, which ultimately contributes to an increase in their income (Orlova & Nikolaev, 2022). In addition, the quality of products that are better maintained during storage also provides added value for agricultural products that are marketed.

The relationship between this case study and the overall data from various regions shows a similar pattern. The post-harvest storage and processing technology applied in the Southern region can be used as a model for other regions that have similar agricultural characteristics. This confirms that the right technological approach, supported by adequate infrastructure, can significantly reduce yield losses and provide long-term benefits for the agricultural sector in Russia

The summary of the results of this study shows that post-harvest storage and processing technology in Russia has a significant impact in reducing agricultural product loss. Data collected from various major agricultural regions in Russia show a reduction in post-harvest losses by up to 50% after the application of the technology (Kostenko, 2020). Cold storage and modified atmosphere treatment technologies have proven to be very effective in maintaining the quality of agricultural products and extending shelf life. The use of this technology not only improves operational efficiency, but also helps increase farmers' income.

Discussions of these results with other studies have shown similarities in the effectiveness of post-harvest storage technologies in countries with extreme climatic conditions. Research conducted in Canada and several countries in Europe shows a similar trend, where the application of modern storage technology has also succeeded in significantly reducing post-harvest losses (Uzun dkk., 2021). However, the difference found is in the accessibility of the technology, where Russia still faces challenges in spreading this technology evenly across the region, especially in remote rural areas. Other research emphasizes the importance of supporting infrastructure and policies, which in Russia still need improvement.

The results of this study are an important sign that the adoption of post-harvest storage and processing technology in Russia is not evenly distributed, but it already shows great potential to increase agricultural productivity (Mukhopadhyay dkk., 2021). The decline in post-harvest losses is an indicator that this technology is playing a key role in improving the agricultural system in Russia. Further reflection of these results also shows that the agricultural sector in Russia needs to accelerate the adoption of technology, especially for small and medium-sized farmers, so that the benefits can be felt more widely and evenly. More supportive government policies are needed to accelerate this process.

The implications of the results of this study are clear: the use of post-harvest storage and processing technologies will increase food security in Russia, reduce dependence on food imports, and increase the competitiveness of Russian agricultural products in the global market. The reduction of post-harvest losses will also contribute to the reduction of food waste, which has a positive impact on the environment (Osabohien, 2024). In addition, this technology can help farmers increase their income through reduced production costs resulting from better efficiency. Modern storage technology will also allow Russia to better cope with volatile global food price fluctuations.

Why do the results of this study show the effectiveness of post-harvest storage and processing technology in reducing losses? This technology allows for better control over storage environmental conditions, such as temperature and humidity, which play an important role in maintaining product quality (Wu dkk., 2021). The modified atmospheric treatment also helps slow down the decay process and maintain the freshness of agricultural products for longer. This technology works by addressing the main factors that cause post-harvest damage, such as unstable temperatures and microbial infestation. Therefore, its application gives positive results in reducing losses.

The next step to be taken is to expand access and adoption of this storage technology across agricultural regions in Russia, especially in rural areas that are currently underaccessed (Jian dkk., 2024). Governments and related institutions must play an active role in providing support, both in the form of policies and financial incentives, to accelerate the adoption of this technology by small and medium farmers. Infrastructure development is also a priority so that storage technology can be applied optimally. These measures are crucial to ensure that the entire agricultural sector in Russia can enjoy the benefits of modern storage technology.

CONCLUSION

The study found that the application of post-harvest storage and processing technology in Russia was able to significantly reduce agricultural yield losses by up to 50%, especially in regions that have adopted modified cold storage and atmospheric treatment technologies. These results demonstrate the effectiveness of technology in overcoming the challenge of post-harvest damage, which was previously a major problem in Russia's agricultural sector. These findings make it clear that with wider adoption of the technology, the agricultural sector in Russia can achieve higher efficiency and a more consistent improvement in the quality of agricultural products.

This research provides added value in terms of the application of methods that combine storage and processing technologies that have been proven to be effective in regions with extreme climates such as Russia. However, this research has limitations, namely the lack of long-term data on the impact of technology on environmental sustainability and how it adapts in remote areas that have limited access to technology. Further research is needed to overcome these limitations, as well as explore more affordable solutions for small and medium-sized farmers, so that the benefits of this technology can be felt more evenly across the regions of Russia.

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