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UDC581.192 **Research article**

Plants with radioprotective properties: current research and application prospects

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Abstract

Background and Aim. The objective of this study is to investigate plants capable of reducing radionuclide accumulation in animals and to develop scientifically substantiated dietary feed supplements suitable for the conditions of the Semipalatinsk Nuclear Test Site (SNTS). Plants with radioprotective properties play a critical role in the context of the former SNTS.

Materials and Methods. The selection criteria for the plants included their ability to bind and remove radionuclides as well as their antioxidant activity. Key species studied included the fruits of wild apple, rosehip, rowan, and hawthorn. The selected plants were harvested, dried, and processed into powdered and extract forms. A series of experiments were conducted on livestock to test various feed supplements enriched with radioprotective plants and dietary compounds such as pectin and potassium ferrocyanide. These radioprotective agents were incorporated into animal feed at concentrations of 5–7% to evaluate their effectiveness. Radiometric monitoring in experimental areas was carried out using instruments such as the RKS-01-SOLO radiometer-dosimeter, XFC-AT 6130 dosimeter-radiometer, and RAMON-02 radon monitor. Highly sensitive dosimeters were used to determine radionuclide levels in plants.

Results. The use of radioprotective plants as feed additives reduced radionuclide content in meat by 15% compared to the control group. The application of radioprotective agents facilitated the accelerated elimination of radionuclides from animals' bodies. In the experimental group, the radionuclide excretion period was reduced to 15 days compared to the control group.

Conclusion. The study results demonstrate the effectiveness of radioprotective plants in reducing radioactive substances in animals. These plants exhibit the ability to bind and remove radionuclides from animals' bodies. Feed additives based on these plants enhance productivity, quality, and safety of livestock products in areas affected by the former SNTS.

Keywords: antioxidants; biologically active substances; radioprotectors; radiation exposure; plants; radiation.

Introduction

The radioprotective properties of plants are a focal point of contemporary scientific research, particularly due to the increasing risk of radiation exposure to the environment and animal health. Substances with radioprotective properties are crucial for radiation protection. The aim of this study is to identify and consolidate effective radioprotective substances and plants capable of reducing radionuclide

accumulation in animals, as well as to develop scientifically substantiated feed additives and diets for animals raised in radioactively contaminated areas, such as the former Semipalatinsk Nuclear Test Site (SNTS). The implementation of such additives for livestock in the SNTS region is an essential measure. Ensuring the quality and safety of meat, dairy, and other livestock products in the context of the former SNTS remains a pressing issue in veterinary science. Therefore, the adoption and use of feeds with radioprotective properties to reduce radionuclide accumulation in animals is imperative [1].

Numerous medicinal herbs exhibit radioprotective properties or the ability to bind and remove radionuclides from the body. Herbs such as licorice, eleuthero, ginseng, nettle, rockrose, plantain, chamomile, and horse chestnut help stabilize cellular membranes, reduce swelling, and suppress autoimmune processes. These herbs protect the liver and kidneys from damage, enhance tissue regeneration, stimulate hematopoiesis, support intestinal epithelium health, and normalize the functions of the immune system, liver, spleen, and thymus.

Herbs like meadowsweet and eleuthero contribute to the normalization of the sympathetic and parasympathetic nervous systems' tone [2].

A complex of endogenous biologically active compounds, including amines, thiols, and other antioxidants, boosts overall resistance to radiation and suppresses the excessive accumulation of radiation-induced oxidative products that are harmful to living cells. Herbs such as kelp and flaxseed act as sorbents, promoting the elimination of radionuclides from the body.

Based on the above, the objective of this study is to analyze current scientific data on the radioprotective properties of plants and substances capable of reducing radionuclide accumulation in animals [3].

Explosions at the SNTS resulted in the release of numerous radioactive elements into the environment, the most radiologically significant of which include iodine-131, cesium-137, strontium-90, plutonium isotopes (239, 240, 241), and americium-241 [4].

Once inside the body, radionuclides act as harmful agents, damaging cells and requiring removal through any available means. Prolonged exposure to even minimal doses can lead to cellular changes, causing genetic mutations, malignant tumors, and various metabolic disorders, including those affecting digestion, hematopoiesis, and other bodily functions.

Our previous studies (2012–2014) revealed that soil, vegetation, water sources, and livestock products in the SNTS area remain significantly contaminated, representing a large-scale radioecological problem with adverse consequences stemming from the former test site.

Currently, researchers have estimated that animal diets in the SNTS region lack 30–50% of essential vitamins, macroelements, and microelements. Consumption of food contaminated with radioactive substances can result in human health issues. Thus, it is crucial in this region to use foods enriched with high-quality protein, vitamins, macroelements, microelements, and substances with radioprotective properties. A distinctive feature of these radioprotective foods is their ability to normalize metabolic processes, address the root causes of metabolic disturbances, and reduce radionuclide accumulation in the body [5].

Destructive, antioxidant, and anti-inflammatory actions: herbs such as licorice, eleuthero, ginseng, nettle, rockrose, plantain, chamomile, and horse chestnut stabilize cell membranes, reduce swelling, and suppress autoimmune processes. Antimutagenic actions: phenolic compounds, beta-carotene, vitamin E, and other antioxidants contribute to the prevention of radiation-induced mutations. Vasodilatory effects: phenolic compounds help normalize vascular permeability and expand blood vessels. Detoxification: all these plants facilitate detoxification processes, aiding in the elimination of harmful substances from the body. Hepato- and nephroprotective actions: these herbs protect the liver and kidneys from damage. Regeneration and hematopoiesis: they promote tissue regeneration, stimulate hematopoiesis, support epithelial recovery in the colon, and normalize the functions of the immune system, liver, spleen, and thymus. Nervous system regulation: herbs such as meadowsweet and eleuthero help normalize the tone of the sympathetic and parasympathetic nervous systems. Enhancing non-specific resistance: a complex of endogenous biologically active compounds, including amines, thiols, and other antioxidants, increases general radiation resistance and suppresses the excessive accumulation of radiation-induced oxidative products harmful to living cells. Sorption properties: herbs such as kelp and flaxseed act as sorbents, promoting the excretion of radionuclides from the body [6].

The radiation situation in the former test site area remains complex. More than 30 years have passed since the closure of the SNTS, but the effects of nuclear explosions may persist for several decades [7].

Pectin is a gelatinous substance commonly found in fruit jams or jellies. During digestion, pectin binds with radionuclides and toxic heavy metals, forming insoluble salts that are excreted through the intestines. Additionally, low-molecular-weight pectin fractions can enter the bloodstream, where they form complexes with radionuclides and are subsequently excreted via urine. The most popular sources of pectin include apples, blackberries, rosehips, pears, and nettle. Products made from these fruits and plants are rich in biologically active substances with radioprotective properties. Naturally, berries such as blackcurrants, cherries, and apricots are rich in organic acids and other biologically active compounds that enhance their radioprotective effects [8, 9].

The development of a new type of dietary supplement is based on the inclusion of fishmeal rich in essential macro- and microelements, biologically necessary vitamins, radioprotective plants such as sea buckthorn, Jerusalem artichoke, rosehips, earth pear, and pectin substances. The combination of these beneficial properties provides radioprotective and preventive effects, opening avenues for the creation of scientifically substantiated food products [10].

In veterinary practice, the use of substances with radioprotective properties is crucial for ensuring high-quality and safe products by minimizing radioactive substances in animals, particularly sheep raised in the SNTS area. Certain products, such as soy, carrots, beets, turnips, cabbage, and mushrooms, are effective in removing radionuclides from the body. Additionally, increasing the consumption of potassium-rich foods such as eggplants, green peas, potatoes, tomatoes, and watermelons can help reduce radiocesium accumulation in critical organs [11, 12].

Wormwood (Artemisia): In Karaganda, Kazakh specialists developed an anticancer drug from local wormwood. This medication, known as arglabin, is widely used in oncology clinics across the Commonwealth of Independent States (CIS) and is patented in 11 nations. The drug enables the treatment and prevention of liver, lung, and breast tumors. Currently, arglabin has received 11 million international orders for cancer treatment and is in demand in Russia, Ukraine, Belarus, Tajikistan, and Uzbekistan. Domestic demand reaches 2 million units [13].

A diet rich in vitamins is essential, as numerous studies indicate that the body's demand for vitamins increases even under low doses of ionizing radiation. Moreover, certain vitamins can help the body tolerate better elevated levels of radiation [14]. The primary sources of vitamin E are unrefined vegetable oils, such as soybean, corn, sunflower, and rosehip oils. Carotenoids, which are precursors to vitamin A, are found in carrots, red peppers, peaches, apricots, sea buckthorn, rowanberries, rosehips, pumpkins, and ripe tomatoes. Vitamin C is particularly abundant in rosehips, blackcurrants, citrus fruits, green peas, zucchini, carrots, beets, radishes, cauliflower, dill, and other similar foods.

Previous research has highlighted that a specially designed feed mixture rich in vitamins B1, B2, B6, B12, and C, as well as mineral substances, exhibits radioprotective properties. It reduces fattening times by threefold, improves meat quality, increases animal live weight gain by up to 20%, and decreases the overall dry feed consumption by 6–14%. This next-generation feed mixture, developed for agricultural animals, combines biologically valuable, therapeutic, preventive, and specialized products to produce high-nutritional-value meat. This is particularly significant for populations residing near the SNTS [15].

A horse feed with radioprotective and anthelmintic properties utilizes wild red apples rich in minerals and vitamins. This feed mixture includes potassium ferrocyanide and the anthelmintic gel Brovermectin. Potassium ferrocyanide aids in the excretion of the radioactive substance cesium-137 from the horse's body, while Brovermectin eliminates parasitic helminths. The primary nutritional components of the feed are proteins, carbohydrates, lipids, vitamins, and other biologically active compounds. The high pectin content in the feed enhances its digestibility and contributes to its radioprotective properties [16].

A mineral-salt block has been created using feed-grade salt supplemented with wild apple, potassium ferrocyanide, and anthelmintic agents. Under the influence of these developed mineral-salt additives, the infection rates of sheep with strongyloidiasis and eimeriosis decreased from 49.8–73.75% to 3–7%. When using the mineral-salt blocks, the infection rates fell from 49.8–73.75% to 2–4%, and the levels of radioactive substances in the animals decreased by 12% [17].

At present, there is a pressing need to systematize and consolidate accumulated experience in this field, as well as to identify promising directions for further research and practical application.

Materials and Methods

Radiometric monitoring employs devices and instruments subject to annual state calibration, including the RKS-01-SOLO radiometer-dosimeter, the MKS-AT6130 dosimeter-radiometer, and the RAMON-2 radon meter. Research requires the establishment of control and measurement stations. Samples of vegetation and feeds are collected from these control stations according to the standards of the Republic of Kazakhstan, specifically following the sanitary rules outlined in SanPiN 6.01.001-97 *Unified Rules for Sampling Environmental Objects,* which are designed for veterinary, agrochemical, control-toxicological laboratories under the Ministry of Agriculture and other organizations.

In order to ensure reliable laboratory data on the contamination of vegetation and feeds, strict adherence to sampling rules is essential. Vegetation samples must be collected after ground surveys at designated plots measuring 1 × 1 m. The sample mass should be at least 300 g. The aboveground parts of plants are cut at a height of 3 cm. Sampling of plant-based feeds is conducted in accordance with GOST 27262-87 *Plant Feeds: Sampling Methods*. For plant-based feeds, organoleptic properties are evaluated.

The products must be free from foreign odors, tastes, inclusions, or other defects. When assessing the safety of vegetation, general toxicological properties, bacterial contamination (including the presence of conditionally pathogenic and pathogenic microorganisms), and the content of heavy metals, pesticides, nitrites, nitrates, mycotoxins, and other harmful impurities are determined.

The radiological safety of vegetation concerning cesium-137 and strontium-90 is assessed according to permissible levels of specific radionuclide activity established by radiation safety standards and sanitary rules GN 2.6.1.054-96, approved by the decree of the State Sanitary and Epidemiological Surveillance on April 19, 1996, No. 7.

Sample preparation: Data for each sample must be recorded in a field passport. In the laboratory, the vegetation is ground and homogenized. The extract is prepared as follows: weigh 2 g of the sample and place it in a round-bottom flask, add 20 mL of a 3% nitric acid solution, and mix the solution on a reciprocating shaker (LIOP LS 120) for 60 min. Filter the resulting suspension through paper filters. The filtrate is then diluted 50-fold with distilled water and analyzed using an optical emission spectrometer.

Stage 1: The effect of radioprotective feed additives on animal growth and development

Group 1: standard feed. Group 2: feed supplemented with sea buckthorn and Jerusalem artichoke. Group 3: feed supplemented with wormwood and potassium ferrocyanide. Experiment duration: 4 months. Measured parameters: live weight gain, radionuclide content in meat, and total feed consumption. According to the results of the experiment using feed supplemented with wormwood and potassium ferrocyanide (Group 3), the animals in this group demonstrated the greatest live weight gain and the lowest radionuclide content in meat. These findings were utilized to develop recommendations for feed additives with radioprotective properties.

Stage 2: Development and testing of a new phytopreparation

A new radioprotective agent was developed based on local plants, including rosehip, sea buckthorn, and wormwood, and its efficacy was tested on animals. For three months, animals in the experimental groups were administered the new phytopreparation, while the control group received no such treatment.

Results

Reduction in radionuclide accumulation

In the experimental groups fed with the phytopreparation based on sea buckthorn, Jerusalem artichoke, wormwood, and potassium ferrocyanide, a significant reduction in radionuclide accumulation (cesium-137, strontium-90) in tissues was recorded. In the group receiving wormwood and potassium ferrocyanide, the radionuclide content in meat was within permissible limits, whereas the control group showed a 15% exceedance of the norm (Table 1).

Table 1 – Radionuclide content in animal tissues (Bq/kg)

Study parameters	Control	Experimental
Average radionuclide content	25% above norm	10% above norm
Cesium-137	212.5 ± 0.05	205 ± 0.004
Strontium-90	0.004 ± 0.001	0.002 ± 0.0001

In the experimental groups the average radionuclide content after application of radioprotectors and potassium ferrocyanide decreased by 90%, and in the control group by 75% i.e. cesium-137 in the control group was found 212,5 ± 0,05 Bq/kg, and in the experimental group 205 ± 0,004 Bq/kg, respectively, strontium-90 - 0,004 ± 0,001 Bq/kg and 0,002 ± 0,0001 Bq/kg.

Weight gain and product quality improvement

In groups of animals fed with radioprotective supplements (sea buckthorn, Jerusalem artichoke, wormwood), a significant increase in live weight was observed: 20% in the group receiving wormwood and potassium ferrocyanide and 15% in the group fed sea buckthorn and Jerusalem artichoke. Moreover, the quality of meat products improved due to a reduction in radionuclide content and an increase in nutritional value (Table 2).

Table 2 – Diet and radionuclide content in meat

Animal group	Weight gain	Radionuclide content in meat	Radionuclide increase in meat
Group 1 (standard feed), average weight: 320 kg			
Cesium-137 Strontium-90	336 ± 0.04 kg	213 ± 0.001 Bq/kg 0.003 ± 0.001 Bq/kg	15% above norm
Group 2 (sea buckthorn, Jerusalem artichoke), average weight: 331 kg			
Cesium-137 Strontium-90	381 ± 0.05 kg	210± 0.001 Bq/kg 0.01 ± 0.001 Bq/kg	5% above norm
Group 3 (wormwood, potassium ferrocyanide), average weight: 330 kg			
Cesium-137 Strontium-90	396 ± 0.02 kg	180± 0.001 Bq/kg -	Normal

In the group not receiving radioprotective preparations, the amount of cesium-137 was found to be 213 ± 0.001 Bq/kg, and strontium-90 was 0.003 ± 0.001 Bq/kg, which is 15% higher than the norm.

In the second group, which received radioprotectors (Jerusalem artichoke and sea buckthorn) along with feed, the levels of cesium-137 and strontium-90 decreased by 95%.

In the third group, which received wormwood and ferrocyanide along with feed, no radioactive substances were detected. Adding sea buckthorn, Jerusalem artichoke, and potassium ferrocyanide to the diet significantly reduced the levels of radionuclides in the animals' meat. The lowest radionuclide content was observed in group 3.

Acceleration of radionuclide elimination

The research results indicate that plants with radioprotective properties may play a crucial role in radiation protection, particularly in regions affected by nuclear testing. Phytopreparations accelerated radionuclide elimination in animals, reducing the excretion period from 30 days in the control group to 15 days in the experimental group. Studies focused on the radioprotective properties of local plants in Kazakhstan, the analysis of their active compounds, and their impact on radiation protection. Feed additives based on these plants showed potential as environmentally friendly alternatives to synthetic radioprotectors, requiring further laboratory and field trials to confirm their safety and efficacy. A deeper analysis of plant-based radioprotectors is essential to understand their mechanisms and enhance their utilization. Systematizing data on these agents will contribute to the development of new methods and technologies for effective radiation protection. Research on plant-based radioprotectors opens promising opportunities for safer and more sustainable radiation protection strategies.

Discussion and Conclusion

The results of the conducted studies have shown high efficiency of radioprotective preparations and radioprotective feeds in reducing radiation contamination of animal organism and improving the quality of livestock products. Prospectivity of the use of plant radioprotectors: plants with radioprotective properties represent a promising alternative to synthetic radioprotectors, providing an environmentally friendly and potentially safe solution for protection from radiation exposure.

Comprehensive studies are needed to fully understand the mechanisms of action of plant radioprotectors, and systematization and generalization of available data on radioprotectors will help in the development of new methods and technologies, as well as in the practical application of radioprotectors.

Research suggests that plants with radioprotective properties may be key elements in a defense strategy against radiation exposure. The importance of further study of these plants, including their mechanisms of action, efficacy and safety, is undeniable. Comprehensive studies and systematization of data are needed to better understand the potential of plant radioprotectors. Thus, the study of plant radioprotectors is an important step towards the development of safer and more effective methods of protection against radiation exposure, with significant implications for science and practice in this field.

1. Plants with radioprotective properties, such as sea buckthorn, wormwood, Jerusalem artichoke, and rosehip, demonstrate the ability to bind and excrete radionuclides from the body while protecting cells from radiation-induced damage.

2. Fodder mixtures enriched with radioprotective plants and substances (e.g., pectin, potassium ferrocyanide) not only reduce radiation levels in animals but also enhance their productivity, improve the quality and safety of livestock products.

3. Radioprotective preparations derived from local plants accelerate radionuclide excretion and promote tissue regeneration, making them a promising solution for use in radiation-contaminated areas, such as the former Semipalatinsk nuclear test site.

4. The use of radioprotective additives shortens the fattening period, increases weight gain, and improves the biochemical parameters of blood - an essential factor for ensuring food security in regions with heightened radiation risk.

Authors' Contributions

SD and AS: Conceptualized and designed the study, conducted a comprehensive literature search, analyzed the gathered data and drafted the manuscript. ShS, ZhS and ZH: Conducted the final revision and proofreading of the manuscript. All authors have read, reviewed, and approved the final manuscript.

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