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MICROWAVE GRAIN DISINFECTION: A PROMISING TECHNOLOGY FOR CROP PRESERVATION

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Abstract: The article examines the problem of protecting cereal crop harvests from pests and microorganisms. The disadvantages of traditional methods of grain disinfection are analyzed. The prospects of using ultra-high-frequency (microwave) radiation as an alternative method are substantiated. The physical principles of microwave heating, the mechanism of microwave radiation's effect on pests and microorganisms, as well as the main components of microwave grain disinfection equipment are described. The advantages and disadvantages of the method, along with the prospects for its use in the agro-industrial complex, are presented.
Keywords: Grain disinfection, microwave radiation, grain pests, microorganisms, grain storage, agro-industrial complex.

Grain occupies a crucial position in the global food system, serving not only as a fundamental component of human nutrition but also as a key source of feed for livestock. Its role in ensuring food security and maintaining the stability of agricultural production cannot be overstated. Despite its importance, grain is highly vulnerable to damage during storage. Over time, stored grain can be attacked by a wide variety of pests, including harmful insects such as the grain borer, weevils, and various moth species, as well as mites and a broad spectrum of microorganisms, including mold-forming fungi and pathogenic bacteria. These biological threats can cause significant quantitative and qualitative losses. Infestations often result in a measurable reduction in grain mass and noticeable deterioration in its physical and sensory characteristics, such as color, odor, texture, and taste. Moreover, the activity of pests and microorganisms may lead to a decrease in the grain's nutritional value, destruction of valuable proteins and vitamins, and the accumulation of toxic metabolites or mycotoxins. Such contamination not only diminishes the market value of the product but can also make it hazardous or entirely unfit for human consumption and animal feed. If left uncontrolled, these processes can undermine both the economic profitability of grain production and the safety of the food supply chain.

The problem of preserving cereal crop yields is one of the key challenges of the agro-industrial complex. As a staple food product, grain is vulnerable to various pests (insects, mites, rodents), microorganisms (bacteria, mold fungi), and diseases, which cause significant quantitative and qualitative losses. Traditional methods of grain disinfection—such as chemical fumigation, treatment with heated air, or gamma irradiation—have a number of drawbacks, including toxicity to humans and the environment, the potential for pests to develop resistance, changes in the physicochemical properties of the grain, and high energy consumption.

Therefore, the development and implementation of new, effective, and environmentally safe grain disinfection methods is a pressing need. One promising approach is the use of ultra-high-frequency (microwave) radiation. The microwave disinfection method is based on the ability of electromagnetic fields in the microwave range to penetrate deep into the grain mass and heat the moisture contained in both the grain and the bodies of pests and microorganisms. This results in their death due to protein coagulation and the destruction of cellular structures [2,3].

Physical Principles of Microwave Heating

Microwave radiation is electromagnetic waves with frequencies ranging from 300 MHz to 300 GHz. Unlike surface-heating methods, microwave energy penetrates deep into the material,

causing volumetric heating. This occurs due to dielectric losses, which result from the interaction of the microwave's electric field with molecules possessing a dipole moment, primarily water molecules [4].

Water molecules with a dipole moment, when exposed to an alternating electric field of a microwave wave, begin oscillating, attempting to align their dipole moments with the field direction. This generates internal friction and heat release. The heating intensity depends on the dielectric properties of the material, the frequency, and the power of the microwave radiation [5].

Effect of Microwave Radiation on Grain Pests

Microwave radiation has a lethal effect on grain pests at various stages of development (eggs, larvae, pupae, adults). The mechanism of pest death is due to several factors:

Thermal effect: The most significant factor is heating the insect's body to lethal temperatures (about 50–60°C) through absorption of microwave energy.

Destruction of cellular structures: Microwave radiation can denature proteins, disrupt cell membranes, and cause other structural damage.

Disruption of metabolic processes: Microwave exposure can interfere with normal metabolic processes in insects, leading to their death.

It is important to note that the effectiveness of microwave disinfection depends on the pest species, its developmental stage, the grain's moisture content, the microwave power, and the treatment duration.

Effect of Microwave Radiation on Microorganisms

Microwave radiation also has bactericidal and fungicidal effects, suppressing the growth of pathogenic microorganisms in grain. The mechanism is similar to that observed in insects:

Thermal effect: Heating microorganisms to lethal temperatures (typically above 60°C) leads to their death.

Destruction of cellular structures: Microwave radiation can damage cell walls, membranes, and DNA of microorganisms.

Disruption of metabolic processes: Microwave exposure can inhibit enzymatic activity and disrupt other metabolic processes in microorganisms.

The efficiency of microwave disinfection against microorganisms depends on the microorganism type, its concentration, the grain's moisture content, the microwave power, and the processing time [6].

Microwave grain disinfection is an innovative and promising approach to solving the problem of crop preservation. Unlike traditional chemical-based methods, microwave treatment offers an environmentally safe and effective alternative capable of destroying pests and microorganisms without harming the environment or human health.

The analysis shows that microwave disinfection has significant advantages, including high processing speed, the potential for process automation, preservation of grain quality, and reduction of storage losses. However, certain disadvantages should be considered, such as high equipment cost and the need for strict process parameter control.

Continued research and innovation in the field of microwave technology hold substantial potential for transforming post-harvest grain protection practices. Efforts directed towards reducing the manufacturing and operational costs of microwave disinfection equipment, enhancing its energy efficiency, and refining processing parameters will contribute to making this method more economically viable and technologically competitive in the agricultural sector. Wider accessibility of such systems could allow even small and medium-sized enterprises in the agro-industrial complex to adopt them, ensuring that effective grain protection is not limited to large-scale operations.

The integration of microwave-based disinfection into grain storage and processing facilities would not only help in drastically reducing post-harvest losses but would also contribute to the preservation of the nutritional and sensory qualities of grain products. By effectively eliminating harmful insects, mites, and microorganisms without relying on chemical agents, this approach aligns with the principles of environmentally friendly and sustainable agriculture.

Moreover, the adoption of microwave disinfection can play an important role in strengthening national and global food security. It minimizes the risk of contamination, prolongs storage life, and ensures that grain supplies remain safe and marketable over extended periods. In the long term, such technological advancements can support the development of an agricultural industry that prioritizes both productivity and ecological responsibility. This will not only safeguard harvests but also promote the production of high-quality, clean, and safe food products that meet the growing demands of both domestic and international markets.

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