Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

# Advances in Halogenation Treatment to Improve Seed Storability

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A seed is a mature, fertilized ovule that is stored with food and a protective seed coat, and is the fundamental unit of plant reproduction as it enables a plant to endure unfavorable conditions and develop into a new plant when conditions are appropriate. Halogenation is a process of seed storability that involves the treatment of seeds with compounds that include halogen, like chlorine or iodine, to enhance the seed stores shelf life and inhibit microbial load, insect infestation, and surface pathogen which destroys the seed quality in storage, although excessive or uncontrolled halogenation can damage the seed envelop, interfere with enzyme action, and reduce germination capacity and consequently, halogenation ought to be carefully controlled to enhance shelf life without harming seed quality.

**Keywords:** Seed treatment; Seed halogenation; Seed storage; Seed deterioration; Seed vigour; Seed viability

## Introduction

Seed is a living biological entity, and seed ageing is an inevitable physiological process that begins during seed development and continues throughout storage. Seed deterioration during storage results in loss of viability, reduction in vigour, biochemical degradation, microbial invasion, and decline in field performance. Rapid loss of seed quality during storage is one of the major constraints faced by the seed industry worldwide. Although seed ageing cannot be completely arrested, it can be significantly delayed by adopting appropriate storage technologies and seed treatments. Among the various seed enhancement technologies, halogenation treatment has emerged as an innovative and promising pre-storage seed treatment technique to improve seed storability. Halogenation involves the application of halogen compounds such as chlorine, bromine, iodine, and fluorine to seeds in order to control seed-borne microflora, stabilize seed membranes, reduce oxidative stress, and prolong seed viability during storage. Recent advances in halogenation research have improved its effectiveness, safety, and applicability for large-scale seed storage.

## Concept of Seed Storability

Seed storability refers to the ability of seeds to remain viable and vigorous for a prolonged period under storage conditions. Storability is determined by genetic, physiological, environmental, and storage-related factors. Seed ageing is characterized by loss of membrane integrity, lipid peroxidation, enzyme inactivation, DNA damage, and accumulation of reactive oxygen species (ROS). Several factors influence seed storability, including seed maturity, moisture content, genetic makeup, mechanical injury, seed coat characteristics, respiration rate, enzymatic activity, oxidative stress, storage temperature, relative humidity, oxygen concentration, seed-borne microorganisms, insects, rodents, storage structures, packaging materials, and post-harvest handling practices. Proper management of these factors is essential for maintaining seed quality during storage.

## Seed Halogenation: Concept and Purpose

Seed halogenation is defined as the treatment of seeds with halogen compounds to reduce microbial contamination, slow physiological deterioration, enhance antioxidant activity, and improve seed longevity and germination performance during storage. Halogenation treatments provide a protective mechanism at the beginning of storage, alleviating deteriorative seed senescence and protecting seeds against extrinsic factors such as pathogens and insects. Halogen treatments are applied either as dry dressing or vapour treatment, depending on the nature of the halogen compound and storage requirements. These treatments have been shown to reduce lipid peroxidation, stabilize lipoprotein membranes, and delay physiological and pathological deterioration of seeds during storage.

## Types of Halogenation Treatments

1. **Dry Dressing**

Dry dressing involves coating seeds with halogen compounds mixed with inert carriers such as calcium carbonate, chalk, talc, charcoal, or activated clay. The halogen chemical is either exposed to vapours and absorbed by the carrier or directly mixed with the carrier in specific concentrations. Seeds are dressed with the mixture in a closed container and kept for 24–72 hours for equilibration. Calcium carbonate is considered the superior carrier due to its stability and uniform distribution of halogens.

2. **Vapour Treatment**

Vapour treatment involves exposing seeds to halogen vapours in a closed container for a specific duration (16–72 hours) at very low concentrations. Halogens such as chlorine, bromine, and iodine, as well as alcohols like ethanol and methanol, are commonly used. Vapours are generated using chemical reactions (e.g., potassium iodide with sulphuric acid) in desiccators or sealed containers. Vapour treatments provide uniform penetration and surface sterilization without direct contact with liquid chemicals.

## Types of Halogenation

1. **Chlorination**

Chlorination involves the use of chlorine compounds such as chlorine gas, sodium hypochlorite, and calcium hypochlorite. Chlorine acts as a strong disinfectant and reduces seed-borne pathogens, thereby improving seed quality and storability. Sodium hypochlorite is commonly used due to its availability and effectiveness, while calcium hypochlorite provides sustained antimicrobial action.

2. **Bromination**

Bromination involves the use of bromine compounds to control microorganisms affecting seed viability. However, due to its higher toxicity, bromination is less commonly used in seed treatment.

3. **Iodination**

Iodination involves the application of iodine or iodine compounds such as potassium iodide. Iodine has strong antimicrobial properties and has been extensively studied for improving seed longevity and storability.

4. **Fluorination**

Fluorination involves the use of fluorine compounds, but it is rarely used in seed treatment due to its high reactivity and toxicity.

## Effect of Halogenation on Seed Microflora

1. **Reduction of Seed-borne Pathogens**

Halogenation has strong antimicrobial effects, penetrating seed coats and inactivating fungal spores such as *Aspergillus*, *Penicillium*, and *Fusarium*. Bacterial populations on seed surfaces are also reduced, leading to healthier seeds and lower disease incidence.

2. **Control of Storage Fungi**

Halogenation suppresses storage fungi growth, minimizes mycotoxin production, reduces seed respiration, and improves seed viability and storability.

3. **Preservation of Seed Viability**

By reducing enzymatic degradation and lipid peroxidation caused by microbial activity, halogenation helps maintain germination percentage and seed vigour over prolonged storage.

4. **Effect on Beneficial Microflora**

Halogenation may eliminate beneficial or neutral microorganisms and cause mild phytotoxic effects if dosage is not optimized, highlighting the importance of dosage optimization.

5. **Improved Seed Hygiene**

Halogen-treated seeds have reduced microbial load and cleaner surfaces, resulting in better field emergence and reduced seed-borne infections.

## Reasons for Improved Seed Quality After Halogenation

1. **Disinfection and Pathogen Control**

Halogen compounds destroy pathogenic fungi and bacteria on seed coats, preventing decay during storage and germination. This leads to improved seed health, germination, and seedling vigour.

2. **Reduction of Seed Deterioration**

Halogens deactivate free radicals and slow oxidative damage to membranes and enzymes, extending seed storability and viability.

3. **Improved Oxygen Uptake and Enzyme Activation**

Halogen vapours modify seed coat properties, improving oxygen diffusion and water imbibition during germination. They also stimulate enzyme activity involved in early germination metabolism.

4. **Biochemical Stimulation**

Low doses of halogens may act as mild chemical stressors, inducing protective proteins, antioxidants, and hormones, thereby enhancing seed vigour and stress tolerance.

5. **Improvement in Seed Surface Properties**

Halogenation alters seed surface properties, improving moisture absorption, coating uniformity, and adhesion of beneficial polymers or microbes in subsequent treatments.

## Advantages of Halogenation Treatment

Halogenation offers several advantages:

- Maintains high germination during storage
- Protects seeds from storage pests
- Reduces storage fungi significantly
- Enhances early plant growth
- Increases root intensity and leaf area
- Improves chlorophyll cycle
- Non-toxic at recommended doses
- Uses easily available and low-cost materials

## Disadvantages and Limitations

Despite its benefits, halogenation has some limitations:

- Treatment process can be time-consuming and labour-intensive
- Improper dosage may cause phytotoxicity
- Potential reduction in photosynthetic efficiency due to changes in fluorescence and triplet lifetime
- Requirement of controlled application techniques to avoid seed damage

## Advances and Research Evidence in Halogenation

1. **Maize Hybrid COH (M)6**

Research at Tamil Nadu Agricultural University showed that halogenation mixture at 3 g $kg^{-1}$ improved seed longevity when combined with appropriate storage containers. Seed vigour parameters were maintained during 10 months of storage under ambient conditions.

2. **Chilli Seeds**

Field and laboratory experiments in Kerala Agricultural University demonstrated that iodine crystal with carrier at 50 mg $kg^{-1}$ and calcium oxychloride at 2 g $kg^{-1}$ significantly enhanced storage life, germination, and seedling performance in chilli.

3. **Blackgram**

Iodination of blackgram seeds at 500 mg for 12–24 hours with calcium carbonate carrier improved germination, shoot length, root length, and dry matter production during long-term storage.

4. **Groundnut and Sesame**

Studies revealed that halogen vapour and halo polymer treatments improved germination and vigour parameters during storage, with significant differences among treatments and storage periods.

5. **Rice Seed Treatment with Iron Chlorine E6**

Seed soaking with iron chlorine E6 at optimal concentrations improved rice seed germination, seedling growth, chlorophyll content, and regeneration ability, demonstrating growth-promoting effects of halogen-based priming.

6. **Halogenated Seeds in Storage**

Halogenation with iodine or chlorine has been shown to prolong seed shelf life and prevent multiplication of seed-borne pathogens and insects during storage. Comparative studies indicate that iodination is more effective than chlorination in prolonging storability. Halogenation provides a low-cost, sustainable method to maintain seed viability under ambient storage conditions.

## Future Prospects and Advances

Advances in halogenation treatment include:

- Dosage optimization to maximize benefits and minimize toxicity
- Development of carrier-based formulations and polymers for controlled release
- Integration with modern storage technologies such as controlled atmosphere and moisture-proof packaging
- Understanding molecular mechanisms of halogen–seed interactions
- Application in seed conservation and germplasm storage

## Conclusion

Halogenation treatment represents an effective, eco-friendly, and low-cost strategy to improve seed storability. By reducing seed-borne microorganisms, slowing physiological ageing, stabilizing membranes, and modulating oxidative stress, halogens significantly enhance seed longevity, viability, and vigour. Advances in application techniques, dosage optimization, and understanding of biochemical and molecular mechanisms have improved the safety and effectiveness of halogenation treatments. Research evidence across various crops demonstrates its potential to enhance seed quality, field performance, and crop productivity. Therefore, halogenation treatment offers a promising approach for extending seed longevity, strengthening seed storage practices, and supporting sustainable seed production and conservation.

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