SUNSHINE AGRICULTURE e-Newsletter

ISSN (E): 2583 – 0821

Sun. Agri.:e- Newsletter, (2025) 5(5), 20-22

Article ID: 399

Polyamines as Edible Coating Material for Shelf-Life Extension in Fruits

Pavankumar T[1], Athira[2], Anam[3], Ganesh Kumar Choupdar[4]

[1]Ph.D. Research Scholar Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute,New Delhi -110012 India

[2]Ph.D. Research Scholar Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi -110012 India

[3]Ph.D. Research Scholar Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110012 India

[4]Ph.D. Research Scholar Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi -110012 India

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Available online at
http://sunshineagriculture.vitalbiotech.org/

Article History
Received: 08. 05.2025
Revised: 13. 05.2025
Accepted: 17. 05.2025

INTRODUCTION

Postharvest spoilage of fruits leads to significant economic losses, especially in developing nations. This spoilage is primarily caused by respiration, ethylene production, water loss, microbial attack, and enzymatic activities. Edible coatings have emerged as a viable technique to mitigate these effects. Among the many compounds used, polyamines have shown remarkable promise due to their multifunctional biological roles. This article explores the potential of polyamines as edible coatings in extending the postharvest life of fruits.

2. What Are Polyamines?

Polyamines (PAs) are small aliphatic amines containing two or more amino groups. They are present in all living organisms and are essential for cellular processes such as DNA stabilization, protein synthesis, and membrane integrity. In plants, polyamines play significant roles in growth regulation, stress response, and senescence.

3. Types of Polyamines in Plants

The three most common polyamines in higher plants are:

- **Putrescine (Put):** The simplest diamine derived from ornithine or arginine.
- **Spermidine (Spd):** Formed from putrescine by the addition of an aminopropyl group.
- **Spermine (Spm):** Synthesized from spermidine by further addition of an aminopropyl group.

These polyamines differ in their physiological roles and affinities for nucleic acids and proteins.

4. Sources for Commercial Isolation of Polyamines

Polyamines can be extracted from:

- **Plant sources:** Soybeans, tomatoes, mushrooms, citrus fruits, and cereals.
- **Microbial fermentation:** Genetically modified microorganisms can produce high yields of polyamines.
- **Chemical synthesis:** Industrial methods are used but less favored due to cost and purity concerns.

5. Polyamine Biosynthesis Pathway

Polyamines are synthesized through two major pathways:

- **Ornithine Pathway:** Ornithine decarboxylase (ODC) converts ornithine to putrescine.
- **Arginine Pathway:** Arginine decarboxylase (ADC) converts arginine to agmatine, which is converted to putrescine.

From putrescine:

- Spermidine is synthesized via spermidine synthase using decarboxylated S-adenosylmethionine (dcSAM).
- Spermine is formed from spermidine by spermine synthase.

6. Ethylene Biosynthesis Inhibition by Polyamines

Ethylene is a plant hormone that accelerates fruit ripening. Polyamines inhibit ethylene biosynthesis by competing for the common precursor S-adenosylmethionine (SAM). This reduces ethylene levels, delaying senescence and extending shelf life.

Mechanism:

- SAM → Ethylene (via ACC synthase and ACC oxidase)
- SAM → Polyamines (via SAM decarboxylase)

By diverting SAM towards polyamine synthesis, ethylene production is reduced.

7. Role of Polyamines in Postharvest Life of Fruits

Polyamines help in:

- **Maintaining fruit firmness** by stabilizing cell walls and membranes
- **Reducing microbial decay** due to antimicrobial activity
- **Delaying color change and ripening** through ethylene suppression
- **Minimizing oxidative damage** via antioxidant enzyme induction

Fruits like banana, papaya, apple, and peach have shown improved shelf life with polyamine treatments.

8. Factors Affecting Efficiency of Polyamine Coating

Several factors influence the success of polyamine coatings:

- **Concentration and type of polyamine**
- **Fruit type and maturity stage**
- **Environmental conditions (temperature, humidity)**
- **Coating method and exposure time**
- **Combination with other bioactive agents**

9. Advantages and Disadvantages of Polyamines

Advantages:

- Naturally occurring and safe
- Effective at low concentrations
- Delay ripening and senescence
- Can be combined with edible film matrices

Disadvantages:

- Variation in efficiency across different fruits
- May cause phytotoxic effects at high doses
- Regulatory barriers for commercial adoption

10. Methods of Coating

Common methods include:

- **Dipping:** Immersing fruits in polyamine solution
- **Spraying:** Uniform application on fruit surface
- **Incorporation in edible films:** Blending with biopolymers such as chitosan, alginate, or cellulose

11. Challenges and Future Directions

Challenges:

- Lack of standardized protocols for different crops
- Limited awareness among farmers and industries
- Storage and stability of polyamine formulations

Future Directions:

- Use of nanoencapsulation for controlled release
- Integration with sensors and smart packaging
- Development of multi-functional coatings with antimicrobial and antioxidant additives

12. CONCLUSION

Polyamines offer a promising solution to extend the shelf life of fruits through their multiple physiological benefits. Their natural origin, combined with effectiveness in reducing spoilage, makes them ideal candidates for edible coatings. With further research and commercial validation, polyamine-based coatings can significantly contribute to reducing postharvest losses and improving food security.

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