AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 11 (November, 2026)
Available online at http://www.agrimagazine.in
©Agri Magazine, ISSN: 3048-8656

Cushioning Materials in Fruits and Vegetables: Types, Functions and Applications

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Cushioning materials play an important role in the postharvest handling, packaging, storage and transportation of fruits and vegetables. Fresh horticultural produce is highly susceptible to mechanical damage caused by impact, vibration, compression and abrasion during harvesting, grading, packing and distribution. Such injuries may result in bruising, tissue breakdown, increased moisture loss, microbial infection and reduced market quality. Cushioning materials are therefore used inside packaging containers to absorb shocks, reduce movement and separate individual fruits and vegetables from one another and from hard container surfaces. Common materials include paper, corrugated cardboard, molded pulp, foam, expanded polyethylene, bubble wrap, wood shavings and biodegradable plant-based materials. The selection of an appropriate cushioning material depends on the type of produce, its size, weight, surface characteristics, transportation distance, cost and environmental impact. Sustainable alternatives such as molded agricultural fibres and biodegradable cushioning materials are increasingly important in reducing plastic waste. Proper cushioning, combined with suitable packaging design, temperature management and careful handling, can minimise postharvest losses and maintain the quality and shelf life of fresh produce.

Keywords: Cushioning materials, fruits, vegetables, postharvest handling, packaging, mechanical damage, biodegradable materials, postharvest losses.

Introduction

Fruits and vegetables are perishable commodities that can be damaged easily during harvesting, handling, packaging, storage and transportation. Unlike many durable agricultural products, fresh produce often has delicate skin, high moisture content and soft tissues that are vulnerable to mechanical injury. Bruising and abrasion can reduce consumer acceptability, accelerate deterioration and increase the risk of decay. Cushioning materials are protective materials placed inside packages or between individual produce items to reduce the force transmitted during impacts and vibrations. They help minimise direct contact between produce and packaging surfaces, restrict excessive movement and distribute pressure more evenly. Their use is particularly important for delicate fruits such as mango, apple, pear, peach, grapes and papaya, as well as easily damaged vegetables such as tomato and leafy vegetables. The effectiveness of cushioning depends on the material's thickness, resilience, compressibility, shock-absorbing capacity and ability to retain its protective properties during transportation. Appropriate cushioning should be selected according to the mechanical sensitivity of the produce and the expected handling conditions.

Types of Cushioning Materials

Paper and cardboard: Paper sheets, shredded paper, corrugated cardboard and paperboard dividers are commonly used to protect produce during packing and transportation. They help reduce friction, absorb minor impacts and prevent fruits from coming into direct contact with one another. Corrugated cardboard inserts are useful for apples, pears, mangoes and other

fruits requiring individual separation. Paper-based materials are lightweight and recyclable, although their cushioning performance may decrease when they become wet.

Plastic foam and bubble wrap: Polyethylene foam, foam nets and bubble wrap are used to absorb impacts and protect delicate produce from abrasion. Foam sleeves are commonly placed around individual fruits, while bubble wrap may be used for selected high-value produce during careful handling and transport. These materials can provide effective cushioning, but their disposal and recycling require consideration because many are made from synthetic plastics.

Molded-pulp trays: Molded-pulp trays are produced from paper fibres or recycled paper materials shaped into individual compartments. Each compartment holds a fruit separately, limiting movement and reducing direct contact between adjacent fruits. They are suitable for apples, pears and other produce with relatively uniform sizes. Molded-pulp packaging can provide a useful alternative to some plastic inserts, although its resistance to moisture and compression.

Natural and agricultural cushioning materials: Rice straw, dry grass, suitable leaves and other locally available plant materials have traditionally been used as cushioning materials. These materials can fill empty spaces, separate produce and reduce direct impact during transport. They are often inexpensive and readily available in agricultural areas. However, they should be clean, dry and free from pests, mould and contaminants to avoid transferring microorganisms or causing damage to the produce.

Plastic trays, dividers and liners: Plastic trays, compartmentalised inserts and liners are designed to hold produce securely and reduce movement within containers. They are useful for delicate fruits, small fruits and selected vegetables. Reusable plastic trays can withstand repeated handling, but their design should allow sufficient ventilation and be easy to clean. Liners should not trap excessive moisture or obstruct the movement of air around the produce.

Functions and Importance of Cushioning Materials

The main purpose of cushioning materials is to reduce mechanical damage during postharvest handling. Their important functions include:

1. **Shock absorption:** Reduces the force transmitted to produce during impact and vibration.
2. **Prevention of bruising:** Minimises internal tissue damage caused by drops, knocks and compression.
3. **Reduction of abrasion:** Prevents scratching and rubbing against hard container surfaces.
4. **Separation of produce:** Limits direct contact between individual fruits and vegetables.
5. **Stabilisation during transport:** Restricts excessive movement inside packaging containers.
6. **Maintenance of market quality:** Helps preserve appearance, firmness and consumer acceptability.
7. **Reduction of postharvest losses:** Minimises damage that may lead to decay and rejection during marketing.

Characteristics of an Ideal Cushioning Material

- **Good shock-absorbing capacity:** It should absorb impact energy and protect produce from mechanical injury.
- **Appropriate softness and resilience:** It should be soft enough to protect delicate tissues and resilient enough to retain its shape during transport.
- **Cleanliness and safety:** It should be free from harmful chemicals, pests, mould and other contaminants.
- **Adequate ventilation:** Its design should permit sufficient airflow and avoid excessive heat accumulation.
- **Moisture resistance:** It should retain its protective properties under the expected humidity conditions.

- **Lightweight and economical:** It should be affordable, easy to handle and suitable for commercial packaging.
- **Environmental sustainability:** It should preferably be reusable, recyclable, biodegradable or compostable where appropriate.

Selection of Cushioning Materials

Produce	Suitable cushioning options
Apple and pear	Molded-pulp trays, paper dividers and foam inserts
Mango and papaya	Foam nets, paper padding and suitable fibre-based inserts
Grapes	Molded trays, protective liners and compartmentalised packaging
Tomato	Paperboard dividers, suitable trays and padded crates
Cucumber	Paper liners, suitable trays and protective dividers
Leafy vegetables	Clean liners and suitable containers that minimise compression while allowing ventilation

Sustainable and Biodegradable Cushioning Materials

Growing concerns about plastic waste have encouraged interest in renewable cushioning materials made from paper fibres, agricultural residues and other biodegradable resources. Rice straw, coconut fibres, moulded agricultural fibres and recycled paper may offer alternatives to conventional plastic cushioning in appropriate applications. However, biodegradable materials must still provide sufficient mechanical protection and must not introduce moisture, contaminants or microorganisms. Their performance should be assessed under realistic transport conditions. Reusable packaging can also reduce material waste when collection, cleaning and return systems are available. Sustainable packaging therefore requires balancing product protection, cost, material use and environmental impact.

Conclusion

Cushioning materials are essential components of postharvest packaging for fruits and vegetables because they help minimise bruising, abrasion, impact damage and transport-related losses. Paper, cardboard, molded-pulp trays, foam nets, plastic inserts and natural agricultural materials can all be useful when selected appropriately. An effective cushioning system should protect the produce without restricting ventilation or creating conditions that encourage deterioration. The adoption of suitable, economical and environmentally responsible cushioning materials, together with careful handling and appropriate storage, can improve the quality and marketability of fresh horticultural produce.

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