



Application of Modified Atmosphere Packaging (Map) for Quality Retention in Minimally Processed Vegetables

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Annotation

In the context of modern food distribution, minimally processed vegetables (MPVs) offer consumers convenience and freshness but remain highly susceptible to quality degradation. Modified Atmosphere Packaging (MAP) has emerged as a non-chemical solution to extend the shelf life of such products by controlling internal gas composition. This study evaluates the effectiveness of different MAP gas ratios ($O_2/CO_2/N_2$) in preserving the color, texture, microbial load, and sensory quality of shredded carrots, sliced bell peppers, and spinach leaves. Preliminary data suggest that high- CO_2 , low- O_2 mixtures significantly slow down respiration rates and microbial growth without compromising appearance or flavor. The findings highlight MAP as a vital postharvest innovation for fresh-cut vegetables in both retail and supply chain contexts.

Keywords: Modified atmosphere packaging, fresh-cut vegetables, respiration rate, shelf-life extension, CO_2/O_2 balance, microbial control, shredded carrots, bell peppers, spinach, postharvest packaging.



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Introduction: With increasing consumer demand for fresh, ready-to-eat vegetables, the market for minimally processed vegetables (MPVs) has expanded rapidly. However, this convenience comes at a cost — MPVs are prone to rapid quality deterioration due to elevated respiration rates, enzymatic browning, moisture loss, and microbial growth after cutting and peeling.

To mitigate these postharvest challenges, Modified Atmosphere Packaging (MAP) has gained recognition as a practical and non-invasive solution. MAP involves altering the composition of gases (primarily oxygen, carbon dioxide, and nitrogen) surrounding the product inside sealed packaging to slow down physiological and microbial spoilage. This approach helps maintain texture, color, and safety without using preservatives.

The specific gas mixture required depends on the respiration characteristics of the vegetable. For instance, leafy greens benefit from low oxygen and elevated CO_2 , whereas root vegetables may require a balanced gas mix to prevent anaerobic fermentation. This study investigates how different MAP configurations impact quality attributes in selected vegetables during cold storage.

Objectives and Research Questions

To ensure a systematic and focused inquiry, this research was guided by the following aims and investigative questions:

Objectives: To assess the impact of various MAP gas compositions on shelf life indicators in MPVs.

To determine optimal gas mixtures for shredded carrots, sliced bell peppers, and spinach leaves.

To evaluate MAP's effectiveness in maintaining visual, textural, and microbiological quality.

To propose application recommendations for MAP in commercial vegetable packaging.

Research Questions:

1. How do different O₂/CO₂/N₂ combinations affect respiration rate and microbial growth in MPVs?
2. Which MAP gas mixture provides the longest shelf life without compromising sensory quality?
3. What role does produce type (leafy vs root vs fruit vegetable) play in MAP performance?
4. Can MAP reduce spoilage in a cost-effective and scalable way for small and medium processors?

Materials and Methods

To examine the effects of MAP on minimally processed vegetables, a controlled experiment was conducted involving three vegetable types and varying gas compositions.

Sample Selection and Preparation: The following vegetables were selected based on their commercial importance and perishability:

Shredded carrots (*Daucus carota*)

Sliced bell peppers (*Capsicum annuum*)

Spinach leaves (*Spinacia oleracea*)

All samples were washed, sanitized (100 ppm chlorine rinse), air-dried, and packed into polyethylene-laminated MAP pouches (O₂ transmission rate: 80 cc/m²/day).

Packaging Conditions: Three MAP gas mixtures were used:

MAP-1: 5% O₂ / 15% CO₂ / 80% N₂

MAP-2: 3% O₂ / 20% CO₂ / 77% N₂

MAP-3: 1% O₂ / 25% CO₂ / 74% N₂

Controls were stored in ambient air (21% O₂ / 0.04% CO₂). All samples were kept at 4°C ± 1°C for 12 days.

Analytical Measurements: Quality was assessed every 3 days for:

Respiration rate (mL CO₂/kg/h): Gas chromatography

Microbial count (CFU/g): Total plate count method

Color stability (ΔE): Colorimeter readings (L*, a*, b*)

Firmness (N): Texture analyzer with flat probe

Sensory attributes: Evaluated by a panel (1–9 scale) for freshness, color, odor, and acceptability

Data were statistically analyzed using ANOVA with Tukey's test (p < 0.05).

Results and Discussion

The application of MAP significantly influenced the shelf life and quality of all tested vegetables. The results are grouped by parameter:

Respiration Rate: MAP-treated samples showed lower CO₂ production compared to the control. The MAP-3 treatment (1% O₂ / 25% CO₂) yielded the lowest respiration rate, particularly in spinach and bell peppers, where metabolic activity was slowed by ~40%.

Microbial Load: Total microbial counts remained below spoilage threshold (6 log CFU/g) for all MAP treatments until Day 9. In contrast, control samples exceeded 7 log CFU/g by Day 6. The high CO₂ content in MAP-3 was most effective in suppressing microbial growth, especially for spinach.

Color and Visual Quality: Color degradation was minimal under MAP conditions. Spinach retained its green pigmentation ($\Delta E < 2.5$) under MAP-2 and MAP-3. Bell peppers in control conditions turned dull and dehydrated by Day 6, while MAP-preserved samples maintained shine and saturation.

Firmness and Texture: Firmness loss was most notable in spinach and carrots. MAP-2 preserved firmness best in carrots (up to 85% retention), likely due to moderated O₂ levels slowing enzymatic softening.

Sensory Evaluation: By Day 9, MAP-2 and MAP-3 samples scored highest ($\geq 7.5/9$) in freshness, odor, and overall appearance. Control samples scored below 5 due to sogginess, discoloration, and off-odors. Consumers preferred MAP-2 for carrots and MAP-3 for spinach.

Conclusion and Recommendations

Modified Atmosphere Packaging presents a reliable method for extending the shelf life and preserving the quality of minimally processed vegetables. Through careful gas composition adjustment, MAP can slow down spoilage while maintaining consumer appeal.

Conclusion: Low O₂ and moderate-to-high CO₂ mixtures significantly slowed respiration and microbial growth in all three vegetables.

MAP-3 (1% O₂ / 25% CO₂) was most effective for spinach and bell peppers, while MAP-2 (3% O₂ / 20% CO₂) worked best for carrots.

MAP-treated samples retained better color, texture, and sensory quality for up to 9–12 days at 4°C.

Recommendations: Use MAP-2 for root vegetables like carrots and MAP-3 for leafy greens.

Incorporate gas flushing equipment and barrier films suitable for the targeted produce.

Promote MAP adoption among local processors to reduce losses and improve marketability.

Further research should test MAP under fluctuating temperature and transport conditions.

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