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COMPARATIVE ANALYSIS OF PACKAGING MATERIALS AND MODIFIED ATMOSPHERIC PACKAGING ON THE POSTHARVEST LIFE OF BROAD LEAF MUSTARD (*Brassica juncea var. rugosa)*

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ABSTRACT

In this study, titled "Comparative Analysis of Packaging Materials and Modified Atmospheric Packaging on the Postharvest Life of Broad Leaf Mustard (Brassica juncea var. rugosa)," conducted in HICAST, Kathmandu, Nepal, from June 13 to June 19, 2023, Investigation of the postharvest condition of 17 kg of freshly harvested broad leaf mustard. The experiment employed four distinct packaging materials—polythene, perforated polythene, muslin cloth, and MAP bags—in addition to a control group, following a Completely Randomized Design with four replications. Critical parameters such as shelf life, weight loss, moisture content, chlorophyll content, total soluble solids (TSS), pH, color, and pathological infection at 3-day intervals was monitored and evaluated. Remarkably, T2 (Polythene) and T3 (Perforated polythene) displayed a meager 3-day shelf life due to rapid decay and saturation, warranting early disposal. T5 (MAP Bag) emerged as the standout performer with a substantial average shelf life of 6 days. Moisture loss was most pronounced in the control group (T1), dropping from 96.76% to 91.2%, whereas T4 (Muslin Cloth) reached 94.82%, and T5 recorded 95.5%. MAP bags (T5) also excelled in preserving chlorophyll content and color stability. In conclusion, findings underscore the superiority of MAP bags, particularly T5, in preserving the postharvest quality and prolonging the shelf life of Brassica juncea var. rugosa, offering a promising solution for enhancing postharvest management in horticulture.

Key Words: Broad Leaf Mustard, MAP Bags, Packaging Materials, Post-harvest, Shelf life

INTRODUCTION

Broad Leaf Mustard (BLM), 2n=36, scientifically known as *Brassica juncea* var. *rugosa*, is a popular leafy vegetable in Nepal, cultivated widely for its affordability and nutritional value (Khatiwada, 2008). Commonly referred to as 'Rayo,' it belongs to the Brassicaceae family and is grown in diverse climates, displaying resilience to frost. BLM, with its short shelf life, requires careful handling to maintain quality (Bhattarai, 2018). Leafy vegetables, including BLM, are crucial for global nutrition, offering a cost-effective source of essential nutrients (Kennedy, 2011; Mohammed & Hussaini, 2023). However, addressing postharvest losses is essential for food security, especially in Nepal, where subsistence farming and high postharvest losses contribute to food insecurity (FAO, 2022; *Thapa et al.,* 2019). Innovative solutions like modified atmospheric packaging can extend shelf life and minimize wastage, contributing to sustainable food production (Lucia & Assennato, 1994).

Postharvest losses, a substantial component of food loss and waste, largely stem from biological deterioration after harvest. Fresh fruits and vegetables deteriorate due to factors like respiration, ethylene production, compositional changes, water loss, physiological disorders, and pathological breakdown (Kader, 2004). Mitigating these losses is essential for sustainable food production.

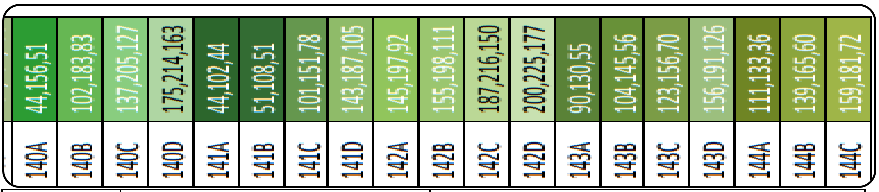
Post-harvest losses indicate quantifiable reductions in both quantity and quality following harvest (Mohammed & Hussaini, 2023). Countries like Nepal grapple with inadequate knowledge of proper practices and technologies, contributing to significant losses in vegetable quality and quantity (Parazuli, 2015). Biological and environmental factors, including transpiration water loss, significantly contribute to postharvest deterioration. Leafy vegetables are deemed unsalable if they lose over 3% of their water content (Ambuko *et al.*, 2017). Broad leaf mustard's cultivation spans 10,851 hectares, yielding 146,756 metric tonnes in Nepal (MoALD, 2022).

Modified Atmosphere Packaging (MAP) involves modifying the atmosphere within a package to enhance shelf life and preserve food quality, achieved either actively or passively (Robertson, 2019). While beneficial, MAP does not replace proper temperature management. Applying passive MAP at non-optimal storage temperatures necessitates finding films with appropriate Oxygen Transmission Rates that align with product respiration rates (Lange, 2000).

MATERIALS AND METHODS

A study conducted at the Himalayan College of Agricultural Sciences and Technology in Nepal examined the postharvest life of Broad Leaf Mustard. The experiment involved using different packaging materials and modified atmospheric packaging. The research utilized ZY No.2 Leaf Mustard and employed a completely randomized design with five treatments.

Treatments:



T1	Control	Broad Leaf Mustard were kept as it is without any treatments.
T2	Polythene Bag	High density polyethylene (HDPE) bags of thickness 40µ were used. No perforations were done.
T3	Perforated Polythene Bag	HDPE bags of thickness 40µ were used by making perforations. Overall, there were 12 perforations.
T4	Muslin Cloth	Muslin cloths were wrapped around the Broad Leaf Mustard.
T5	MAP Bags	Modified atmosphere packaging (MAP) bags which is biodegradable was used as packaging material.

Parameters Observed:

Physical Parameters:

Color: Evaluated using a standardized color chart. The color of the leaves was matched to the closest swatch on the Royal Horticulture Society's color chart to determine color intensity or shade (Royal Horticulture Society, 2019).

Moisture Content/Dry Matter Content: Measured using a precision balance.

$$\textbf{Moisture Content}(\%) = \frac{\text{Initial Weight Of Fresh Sample} - \text{Weight of Oven Dried Sample}}{\text{Initial Weight Of Fresh Sample}} \times 100\%$$

Biochemical Parameters:

Chlorophyll Content: The chlorophyll content was assessed using the Wellburn technique. Broadleaf mustard’s samples weighing 0.2 g was extracted with 7 mL of 80% acetone and the optical density of the solution was measured at 645 nm and 663 nm (Wellburn, 1994). The chlorophyll content was determined by using equation given below:

- Chlorophyll a (mg/g) = (12.70 × A663 - 2.690 × A645) × V / (1000 × W)
- Chlorophyll b (mg/g) = (22.90 × A645 - 4.680 × A663) × V / (1000 × W)
- Total chlorophyll content = chlorophyll a + chlorophyll b

Where, V= Volume of acetone used and W = weight of the fresh cucumber peels

Total Soluble Solid (TSS): Monitored using a digital refractometer.

pH: Measured using a digital pH meter.

Shelf-life Parameters:

Shelf Life: Assessed by monitoring pathological infestations and marketability.

Weight Loss: Measured using a digital weighing machine (Teixeira *et al.*, 2012).

$$\textbf{Weight Loss}(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100\%$$

Spoilage Ratio: Calculated based on the count of spoiled or damaged leaves.

$$\textbf{Spoilage Ratio}(\%) = \frac{\text{Initial Total Fresh Leaf} - \text{Fresh leaf}}{\text{Initial total Fresh Leaf}} \times 100\%$$

Pathological Infection: Evaluated by monitoring microbial growth through swabbing and incubation.

Experimental Design:

Replication: The experiment had four replications for each treatment.

Statistical Analysis: Data analysis was conducted using Excel and GENSTAT software, considering various observed parameters.

RESULTS AND DISCUSSION

The research study titled "Comparative Analysis of Packaging Materials and Modified Atmospheric Packaging on the Postharvest Life of Broad Leaf Mustard (*Brassica juncea* var. *rugosa*)" was carried out, on the 4th day of the experiment, treatments 2 and 3 were excluded from further analysis due to their nearly complete decay and saturation in their own liquid. However, the experiment continued with treatments 1, 4, and 5. Detailed findings from the experiment are presented below:

Physical Parameter

Effect of Packaging Materials on Color

Selected fresh and visually appealing leaves from each treatment group were compared. On the initial observation day, leaf color closely matched 140A on the color chart. The MAP bag notably maintained consistent color throughout storage, aligning with Yang *et al.* (2022) findings. Their study indicated that MAP not only preserved color but also increased vitamin C levels, maintained stable polyphenol content, reduced cell membrane damage, suppressed enzymes related to phenolic metabolism, and mitigated lignin deposition during storage.

Table 1. Effect of Packaging materials on Color of Broad Leaf Mustard

Treatment	Initial Color	Days of Storage	
		Color	
		3rd Day	6th Day
T1 (Control)	140A	140B	141C
T2(Normal Polythene (40µ))	140A	144A	N/A
T3 (Perforated Polythene (40µ))	140A	141C	N/A
T4 (Muslin Cloth)	140A	140A	141C
T5 (MAP bag (35µ))	140A	140A	140A

Effect of Packaging Materials on Moisture Content

Freshly harvested produce, with 65-95% water, is regulated by protective layers with small pores, primarily on leaves (Collalti *et al.*, 2020). The study found an initial moisture content of 96.76%. By the 3rd day, moisture varied significantly. T1 (control) had the lowest at 93.87%, T2 (polythene) decayed to 96.46%, T5 (MAP Bag) maintained freshness at 96.33%, T3 (perforated polythene) showed 95.99%, and T4 (wet muslin cloth) had 95.81%. Treatments 2 and 3 were discontinued on day three due to decay.

On the 6th day, T1 wilted to 91.2%, while T5 (MAP Bag) retained the highest moisture at 95.5%, and T4 recorded 94.83%, preserving freshness. The significant results align with Agüero *et al.*, (2011) on lettuce quality loss, emphasizing water content changes in different storage conditions and variations between outer and inner leaves.

Table 2. Effect of Packaging materials on Moisture Content of Broad Leaf Mustard

Treatment	Initial Moisture Content (%)	Days of Storage	
		Moisture %	
		3rd Day	6th Day
T1 (Control)	96.76	93.87	91.2
T2(Normal Polythene (40µ))	96.76	96.46	N/A
T3 (Perforated Polythene (40µ))	96.76	95.99	N/A
T4 (Muslin Cloth)	96.76	95.81	94.82
T5 (MAP bag (35µ))	96.76	96.33	95.5
Mean		**95.69**	**93.84**
CV %		**0.5**	**1.1**
LSD		**0.71**	**1.76**

Biochemical Parameter

Effect of Packaging Materials on Chlorophyll Content

Chlorophyll is crucial for Broad Leaf Mustard quality, influencing color and freshness. Enzyme-induced degradation, detailed in Table 4 and Appendix 1, follows multi-pathway chlorophyll breakdown (Xiao *et al.*, 2014). Day one average chlorophyll was 0.96 mg/g. By day three, T2 and T3 decayed to 0.15 mg/g and 0.17 mg/g, while the MAP Bag maintained stability at 0.84 mg/g. T1 had 0.46 mg/g, and T4 had 0.55 mg/g. T2 and T3 were discontinued on day four. By day six, T1 and T4 averaged 0.22 mg/g and 0.35 mg/g, respectively, while the MAP Bag retained 0.47 mg/g, double that of T1. Statistical analysis supports the MAP Bag's superior chlorophyll preservation, aligning with Thapa *et al.* (2019).

Table 3. Effect of packaging materials on chlorophyll content of broad leaf mustard

Treatment	Initial Chlorophyll (mg/g)	Days of Storage Chlorophyll Content (mg/g f.w)	
		3rd Day	6th Day
T1 (Control)	0.963	0.46	0.22
T2(Normal Polythene (40µ))	0.963	0.15	N/A
T3 (Perforated Polythene (40µ))	0.963	0.17	N/A
T4 (Muslin Cloth)	0.963	0.55	0.35
T5 (MAP bag (35µ))	0.963	0.84	0.47
Mean		**0.43**	**0.34**
CV %		**32.1**	**47.1**
LSD		**0.21**	**0.28**

Note: f.w = fresh weight

Effect of Packaging materials on TSS

Our research reveals that Broad Leaf Mustard's Total Soluble Solids (TSS) content increases during storage, following an initial steep incline that gradually levels off (Rajak *et al.*, 2014). At the experiment's start, TSS was 2 °Brix. By the 3rd day, T1 had the most significant change, reaching 3.75 °Brix, while T2, T3, T4, and T5 remained stable, indicating a subtle taste alteration. On the 6th day, the control group (T1) showed the highest increase to 5.75 °Brix, T4 reached 5 °Brix, and T5 had the smallest change at 4.25 °Brix, suggesting a relatively sweeter taste in the other treatments compared to the MAP bag. T5 exhibited a more consistent and natural taste. Notably, although T2 and T3 maintained constant TSS levels, they decayed and became unusable.

Effect of packaging materials on pH

Vegetables' pH levels decrease as nutrient constituents diminish (Fimbres-Acedo *et al.*, 2023). On day one, the pH was 5.24, gradually increasing. By day 3, T3 had the highest pH at 8.57, followed by T2 at 8.1 due to decay. T5 showed the least variation with a stable pH of 5.66. T4 increased to 5.98, while T1 reached 5.89.

Table 4. Effect of Packaging materials on TSS of Broad Leaf Mustard

Treatment	Initial TSS (° Brix)	Days of Storage (° Brix)	
		3rd Day	6th Day
T1 (Control)	2	3.75	5.75
T2(Normal Polythene (40µ))	2	2	N/A
T3 (Perforated Polythene (40µ))	2	2	N/A
T4 (Muslin Cloth)	2	3	5
T5 (MAP bag (35µ))	2	3	4.25
Mean		**2.75**	**5**
CV %		**8.1**	**18**
LSD		**0.35**	**1.55**

Treatments 2 and 3 were discontinued on day 4 due to decay. By then, T5's pH was 6.01, T1 and T4 reached 6.51 and 6.61, respectively. pH tends to increase with extended storage of green leafy vegetables, less pronounced in T5 (MAP bag). T4 and T1 also had relatively minor pH alterations.

Table 5. Effect of packaging materials on ph of broad leaf mustard

Treatment	Initial pH	Days of Storage pH	
		3rd Day	6th Day
T1 (Control)	5.24	5.89	6.51
T2(Normal Polythene (40µ))	5.24	8.1	N/A
T3 (Perforated Polythene (40µ))	5.24	8.57	N/A
T4 (Muslin Cloth)	5.24	5.98	6.61
T5 (MAP bag (35µ))	5.24	5.66	6.01
Mean		**6.84**	**6.38**
CV %		**3.9**	**2.7**
LSD		**0.41**	**0.30**

Shelf-Life parameters

Effect of Packaging Materials on Shelf Life

Research shows that T5 (MAP Bags) exhibited the longest average shelf life, approximately 6 days, followed closely by T4 (Wet Muslin Cloth) and T1 (Control) with 4.5 and 4 days, respectively. In contrast, T2 (Polythene) and T3 (Perforated Polythene) had the shortest average shelf life at 3 days. These findings align with Thapa *et al.* (2019), who observed extended shelf life for broadleaf mustard stored in Modified Atmosphere Packaging (MAP) bags.
Broad Leaf Mustard's shelf life is influenced by factors pre- and post-harvest, such as rootstock selection, cultivar choice, cultural practices, harvesting conditions, and maturity stage (Kader *et al.,* 1973). Post-harvest considerations include operational efficiency, pre-cooling methods, treatments like fungicides, and overall storage process efficiency.

Table 6. Effect of Packaging Materials on Shelf Life of Broad Leaf Mustard

Treatment	Average Shelf Life (Days)
T1 (Control)	4
T2(Normal Polythene (40µ))	3
T3 (Perforated Polythene (40µ))	3
T4 (Muslin Cloth)	4.5
T5 (MAP bag (35µ))	6.25
Mean	**4.05**
CV %	**17.3**
LSD	**1.08**

Effect of Packaging Materials on Weight loss

Broad Leaf Mustard faces weight loss after harvest due to factors like transpiration and respiration, causing shrinkage. Leafy greens, with over 90% water content, are particularly vulnerable to such issues. The choice of packaging is crucial to combat these challenges (Mohammed & Hussaini, 2023).
In a 7-day study, significant differences in weight loss were noted. By the 3rd day, losses ranged from 1.51% to 35.34%. The control group (T1) suffered the most, while T2 (Polythene) had the least due to its sealed packaging. T2 and T3 deteriorated quickly. By the 6th day, T4 (Wet Muslin Cloth) had the highest weight loss at 33.08%, and the MAP Bag (T5) had the lowest at 8.70%.

The MAP Bag (T5) maintained freshness, unlike T2, which, despite showing no weight loss, had decayed leaves stuck to the polythene by day 4. T5 persevered, keeping low weight loss and freshness. Statistical analysis validated results on the 3rd and 6th day, aligning with Thapa *et al.* (2019), emphasizing the packaging's crucial role in mitigating weight loss in Broad Leaf Mustard.

Table 7. Effect of Packaging materials on Weight Loss of Broad Leaf Mustard

Treatment	Initial Weight (g)	Days of Storage	
		Weight loss (%)	
		3rd Day	6th Day
T1 (Control)	2435	35.34	39.46
T2(Normal Polythene)	2445	1.51	N/A
T3(Perforated Polythene)	2446	12.88	N/A
T4 (Muslin Cloth)	2487	27.67	33.08
T5 (MAP Bag)	2424	6.07	8.7
Mean		**16.69**	**23.75**
CV		**12.9**	**19.9**
LSD		**3.31**	**8.19**

Effect of Packaging materials on Spoilage

Packaging is vital for preserving leaf lettuce quality, but polymeric films, while reducing deterioration, can introduce issues like moisture and decay. Spoilage in Broad Leaf Mustard was observed in different treatments. By day 3, T3 had the highest spoilage at 94.68%, while the MAP bag had the least at 33.74%. T1 had 65.31% spoilage, and T4 had 77.9%. Despite some wilted leaves in T1, most remained marketable. T2 had the second-highest spoilage. Treatments 2 and 3 decayed and were discontinued by day 4.

By day 6, spoilage was highest in T4 at 89%, followed by T1 at 74.95%, with the MAP bag having the least at 47.8%. MAP bags proved significantly better for long-term storage, reducing spoilage in Broad Leaf Mustard compared to T2, T3, and T4. These results align with Thapa et al. (2019), emphasizing the superiority of MAP bags in decreasing decay and extending shelf life by slowing respiration and reducing moisture loss.

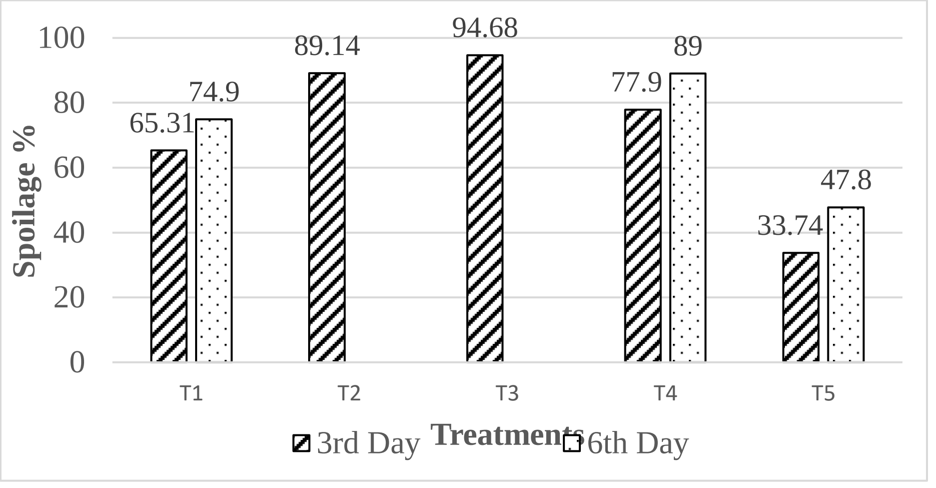


Figure 1. Effect of Packaging materials on Spoilage of Broad Leaf Mustard

Effect of Packaging Materials on Pathological Infection

Pathological diseases challenge Broad Leaf Mustard's postharvest handling, impacting marketability and shelf life. Research on microbial growth found no growth on the 1st and 3rd days. By the 6th day, microbial growth appeared in T1 and T4. T2 and T3 decayed rapidly, submerging in liquids by the 4th day. T4 showed some decay, possibly due to constant moisture. T5 had incipient decay at basal leaf ends, maintaining overall freshness. The control group (T1) had no decay but rapid wilting and yellowing from moisture loss.

In summary, T1 (Control) showed no decay but rapid wilting. T5 (MAP Bag) had minimal decay, maintaining overall freshness. These findings align with Khan (2020) and Thapa *et al.* (2019), emphasizing passive modified atmosphere packaging's efficacy in mitigating postharvest infestations and extending storage life, consistently upholding product quality.

CONCLUSION

In this research investigation, the impact of various packaging materials, particularly Modified Atmospheric Packaging (MAP) bags, on postharvest broadleaf mustard quality was assessed. The findings highlighted the remarkable performance of MAP bags, exemplified by T5, which extended shelf life to an impressive 6 days while minimizing weight loss. Notably, T2 (Polythene), despite indicating less weight loss, concealed complete decay due to its airtight condition.

In contrast, T2 and T3 treatments experienced swift and comprehensive deterioration, leading to early disposal. These results underscore the unparalleled effectiveness of MAP bags in preserving postharvest broadleaf mustard, consistently maintaining critical quality parameters such as color, chlorophyll content, and pH. As such, MAP bags emerge as the superior choice for extending the freshness and longevity of this vegetable during postharvest handling. To address moisture loss, exploring options like T4 & T5 (MAP Bag) which retained higher moisture levels compared to others, is recommended. In terms of superior parameters, MAP bags outperformed all other packaging materials in preserving postharvest Broad leaf mustard quality.

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