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Rashmi
M.Sc. Scholar, Department of Fruit Science, College of Horticulture and Research Station, Saja, Bemetara, Chhattisgarh, India

Johnson Lakra
Assistant Professor, Department of Fruit Science, College of Horticulture and Research Station, Kunkuri, Jashpur, Chhattisgarh, India

Sevan Das Khunte
Assistant Professor, Department of Fruit Science, College of Horticulture and Research Station, Sankara-Patan, Durg, Chhattisgarh, India

Pushpanjali Pankaj
Assistant Professor, Department of Vegetable Science, College of Horticulture and Research Station, Saja, Bemetara, Chhattisgarh, India

Namita Singh
Assistant Professor, Department of Genetics & Plant Breeding, College of Horticulture and Research Station, Arjunda, Balod, Chhattisgarh, India

Chiranjeevi Chandrakar
M.Sc. Scholar, Department of Fruit Science, College of Horticulture and Research Station, Saja, Bemetara, Chhattisgarh, India

Corresponding Author:
Rashmi
M.Sc. Scholar, Department of Fruit Science, College of Horticulture and Research Station, Saja, Bemetara, Chhattisgarh, India

Impact of various bio-extracts and packaging material on the quality and shelf life of Papaya

Rashmi, Johnson Lakra, Sevan Das Khunte, Pushpanjali Pankaj, Namita Singh and Chiranjeevi Chandrakar

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Abstract
A laboratory study titled "Impact of various bio-extracts and packaging material on the quality and shelf life of Papaya" was carried out during 2024-25 at CHRS, Saja, Bemetara (C.G.) to evaluate the role of natural plant-based extracts in preserving the quality of papaya fruits under ambient storage conditions. The experiment was designed in a Completely Randomized Design (CRD) with ten treatments replicated three times. Treatments included aqueous solutions of Aloe vera gel, Neem leaf extract, and Moringa leaf extract at three concentration levels (100%, 75%, and 50%) in combination with newspaper wrapping, along with an untreated control. A total of 300 fruits were used, with 30 fruits assigned per treatment. Data were recorded at 3-day intervals up to 15 days. Results indicated that neem leaf extract, particularly at full strength (100%), was most effective in preserving fruit quality. Fruits treated with neem showed higher levels of reducing, non-reducing, and total sugars, had better flavor, and were rated highest in overall acceptability. Aloe vera extract also enhanced fruit quality and moderately extended shelf life, while moringa leaf extract had a comparatively weaker effect, with treated fruits showing faster deterioration than neem- and aloe-treated fruits. Control fruits spoiled rapidly, with shelf life ending by the 6th day.

Keywords: Papaya, neem leaf extract, Moringa leaf extract and Aloe vera

Introduction
Papaya (*Carica papaya* L.), a fast-growing and short-lived fruit crop of the family Caricaceae, is characterized by its soft stem, large lobed leaves, and prolific fruit-bearing capacity within a brief period. Owing to its short life cycle, papaya is regarded as a highly remunerative fruit crop that provides quick economic returns to farmers. It thrives best in tropical climates, where warm temperatures promote vigorous growth and fruiting. In India, the crop is known by several regional names, including *papaiya* (Gujarati), *papai* (Marathi), *pepe* (Bengali), *papita* (Hindi), *pharangi* (Kannada), *boppayipandu* (Telugu), *omakai* (Malayalam), *pappali* (Tamil), and *pawpaws* in English (Anonymous, 2010) [38].
Papaya is recognized as one of the world's most valuable fruits owing to its rich nutritional composition. Per 100 g of pulp, it provides about 60.9 mg of ascorbic acid, 0.047 mg of vitamin A, and 20 mg of calcium, making a single serving sufficient to fulfill the daily nutritional needs of an individual (Rajasekhar Pinnamaneni, 2017) [24]. Beyond its dietary value, papaya is an important source of papain, an enzyme widely utilized in brewing, pharmaceuticals, food processing, detergents, leather treatment, and meat tenderization. Under optimal cultivation practices, papaya can yield approximately 8.17 g of papain per fruit and up to 686.29 g per plant over six months (Reddy *et al*., 2012) [29]. Globally, papaya production stands at around 128 million tonnes across 43.90 million hectares, with an average productivity of 29.40 metric tonnes per hectare. India is the leading producer, contributing about 38% of global output, with major producing states being Andhra Pradesh, Gujarat, Karnataka, West Bengal, Madhya Pradesh, Maharashtra, and Uttar Pradesh. In Chhattisgarh, papaya production during 2023-24 was recorded at 367.793 thousand metric tonnes from 13.940 thousand hectares (Anonymous, 2023-24), with Bilaspur, Balrampur, Durg, and Mahasamund being the primary producing districts. In Bemetara district alone, the crop covers nearly 0.790 thousand hectares, yielding about 30.230 thousand metric tonnes (Anonymous, 2022-23). However, the perishable nature of papaya poses serious challenges

for storage and transportation over long distances. Fruits are highly susceptible to water loss and fungal infections, resulting in rapid deterioration of quality. Studies have shown that nearly 30-50% of harvested papaya is lost before reaching consumers, primarily due to postharvest spoilage (Mondal and Bose, 2007) [17].

Several strategies are available to preserve the postharvest quality of fruits, but many rely on chemical treatments that pose risks such as residual toxicity, environmental hazards, and adverse health effects. This has increased interest in safer and eco-friendly alternatives. Among these, natural plant extracts have emerged as promising options since they are non-toxic to humans and the environment and are valued for their antimicrobial properties. Polysaccharides are commonly used in edible coating formulations because of their effectiveness in reducing moisture loss and regulating gas exchange, thereby slowing ripening and senescence. Extracted from plant sources, polysaccharides such as cellulose, starch, gums, and chitosan often possess crystalline structures that allow cross-linking, making them more efficient in forming protective coatings (Prasad *et al*., 2018) [39]. Natural bio-extracts like Aloe vera, neem leaf, and moringa leaf extracts are increasingly utilized in food preservation and packaging to extend the shelf life of perishable commodities. Aloe vera, with its high water content and antimicrobial activity, helps retain fruit moisture while suppressing microbial growth. Neem leaf extract, rich in compounds such as azadirachtin, demonstrates potent antibacterial, antifungal, and insect-repellent properties, thereby reducing spoilage. Moringa leaf extract, abundant in antioxidants, vitamins, and antimicrobial agents, delays oxidative changes and maintains both the nutritional and sensory quality of stored products.

Materials and methods

A laboratory study titled "Impact of various bio-extracts and packaging material on the quality and shelf life of Papaya" was carried out during the postharvest season of 2024-25 to evaluate the effect of natural preservative treatments on the biochemical composition and sensory quality of papaya during storage. The experiment was conducted in Bemetara district, located at 22.09˚N latitude and 82.15˚E longitude, which falls within India's Eastern Plateau and Hill Region (Agro-climatic Zone VII). Within Chhattisgarh, Bemetara lies in the plains agro-climatic zone. The experiment was laid out in Completely Randomized Design (CRD) with three replications. The treatments consisted of ten combinations, including a T_0 - Control, T_1 - Aloe vera gel extract (100% Solution) + News paper, T_2 - Aloe vera gel extract (75% Solution) + News paper, T_3 - Aloe vera gel extract (50% Solution) + News paper, T_4 - Neem leaf extract (100% Solution) + News paper, T_5 - Neem leaf extract (75% Solution) + News paper, T_6 - Neem leaf extract (50% Solution) + News paper, T_7 - Moringa leaf extract (100% Solution) + News paper, T_8 - Moringa leaf extract (75% Solution) + News paper and T_9 - Moringa leaf extract (50% Solution) + News paper. The fruits were stored under ambient room temperature, and observations were recorded at 3-day intervals (up to 15 days or end of shelf life).

Results and Discussion

Biochemical Parameters

The mean non-reducing sugar content of papaya increased gradually from 1.64% at 3 days to 2.55% at 15 days, reflecting normal ripening through sucrose accumulation. The low standard error of mean (0.02-0.03) and significant critical difference (CD 0.05-0.09) confirmed the reliability of these observations. Total sugar content, comprising both reducing and non-reducing sugars, also rose over time, from 8.22% at 3 days to 12.77% at 15 days. Fruits treated with neem extract (T_4, T_5, and T_6) consistently exhibited the highest sugar levels throughout storage, reaching up to 12.95% at 15 days, indicating effective extended shelf life. Aloe vera treatments (T_1, T_2, and T_3) showed moderate increases in sugar content (up to 11.84%), while Moringa-treated fruits (T_7, T_8, and T_9) had lower sugar levels and reached the end of their shelf life by day 9. Control fruits (T_0) showed the lowest sugar content by day 6, highlighting the effectiveness of bio-extracts in preserving fruit quality. In conclusion, neem leaf extract treatments proved most effective in enhancing papaya shelf life, followed by Aloe vera gel extract and Moringa leaf extract. These findings are consistent with prior research demonstrating that bio-extracts act by modulating physiological and biochemical pathways, reducing ethylene production, enzymatic browning, and microbial proliferation, thereby extending the shelf life and preserving the sensory and physico-chemical quality of climacteric fruits such as papaya (Banjoko *et al*., 2019) [40] and (Deshmukh *et al*., 2020) [5].

Sensory and Quality Parameters

Neem-treated fruits (T_4-T_6) consistently recorded the highest taste and appearance scores, starting at 8.21 on day 3 and remaining within an acceptable range (7.50-7.72) through day 15. Aloe vera and Moringa treatments provided moderate color retention, whereas control fruits deteriorated quickly, becoming unmarketable by day 6. Taste and flavor improved with ripening across all treatments, with neem-treated fruits achieving the highest scores (up to 8.23) by day 15. Aloe vera treatments showed gradual flavor enhancement until day 12, after which the fruits reached the end of their shelf life. Moringa-treated fruits had lower flavor scores and spoiled by day 9, while control fruits consistently exhibited the poorest taste and flavor quality. Statistical analysis confirmed significance with CD values ranging from 0.17 to 0.33 and low SEM (±0.06-0.11). Overall acceptability, reflecting combined scores for appearance, flavor, texture, and aroma, was highest in neem-treated fruits (T_4-T_6), reaching approximately 8.03 by day 15. Aloe vera-treated fruits maintained acceptable ratings up to day 12, whereas Moringa treatments reached the end of shelf life by day 9. Control fruits consistently received the lowest scores. These differences were statistically significant (CD: 0.18-0.31) with minimal error margins. The enhanced sensory quality in neem and aloe vera treatments can be attributed to their bioactive compounds, including antioxidants and antimicrobials, which mitigate spoilage and oxidative damage, thereby maintaining freshness and consumer appeal. Newspaper packaging likely contributed to moisture regulation and reduced mechanical damage, further preserving fruit quality. Similar results was proposed by Watharkar *et al*., 2017 and Singh *et al*., 2018 [37, 36].

Table 1: Effect of various bio-extracts and packaging material on shelf life of Papaya.

Treatment details	Shelf life (days)
T_0 - Control	8.12
T_1 - Aloe vera gel extract (100% Solution) + News paper	14.03
T_2 - Aloe vera gel extract (75% Solution) + News paper	13.84
T_3 - Aloe vera gel extract (50% Solution) + News paper	13.66
T_4 - Neem leaf extract (100% Solution) + News paper	16.53
T_5 - Neem leaf extract (75% Solution) + News paper	16.37
T_6 - Neem leaf extract (50% Solution) + News paper	16.24
T_7 - Moringa leaf extract (100% Solution) + News paper	11.23
T_8 - Moringa leaf extract (75% Solution) + News paper	11.14
T_9 - Moringa leaf extract (50% Solution) + News paper	10.86
Mean	13.20
SEm (±)	0.60
CD (5%)	1.76

Table 2: Effect of various bio-extracts and packaging material on Total Soluble Solid of Papaya.

Treatment details	Total Soluble Solid (^{o}Brix)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	6.95	8.46	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	7.24	8.93	9.73	10.86	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	7.22	8.89	9.69	10.83	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	7.19	8.85	9.64	10.79	*
T_4 - Neem leaf extract (100% Solution) + News paper	7.35	9.10	9.92	11.03	11.79
T_5 - Neem leaf extract (75% Solution) + News paper	7.33	9.07	9.89	11.00	11.73
T_6 - Neem leaf extract (50% Solution) + News paper	7.31	9.04	9.85	10.97	11.68
T_7 - Moringa leaf extract (100% Solution) + News paper	7.11	8.72	9.50	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	7.08	8.67	9.45	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	7.06	8.64	9.41	*	*
Mean	7.18	8.84	9.68	10.91	11.73
SEm (±)	0.25	0.11	0.08	0.10	0.03
CD (5%)	NS	0.33	0.24	0.30	0.09

***** End of shelf life

Table 3: Effect of various bio-extracts and packaging material on titratable acidity of Papaya.

Treatment details	Titratable acidity (%)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	0.56	0.49	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	0.96	0.84	0.75	0.67	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	0.92	0.80	0.72	0.64	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	0.88	0.77	0.69	0.62	*
T_4 - Neem leaf extract (100% Solution) + News paper	1.12	0.97	0.87	0.78	0.67
T_5 - Neem leaf extract (75% Solution) + News paper	1.09	0.95	0.85	0.76	0.65
T_6 - Neem leaf extract (50% Solution) + News paper	1.05	0.91	0.82	0.74	0.63
T_7 - Moringa leaf extract (100% Solution) + News paper	0.79	0.69	0.62	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	0.74	0.64	0.58	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	0.71	0.62	0.55	*	*
Mean	0.88	0.77	0.72	0.70	0.65
SEm (±)	0.03	0.02	0.02	0.01	0.01
CD (5%)	0.08	0.06	0.05	0.04	0.02

***** End of shelf life

Table 4: Effect of various bio-extracts and packaging material on reducing sugar of Papaya.

Treatment details	Reducing sugar (%)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	5.39	6.47	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	6.77	8.12	9.48	9.54	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	6.70	8.04	9.37	9.44	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	6.63	7.96	9.28	9.35	*
T_4 - Neem leaf extract (100% Solution) + News paper	7.30	8.76	10.21	10.29	10.36
T_5 - Neem leaf extract (75% Solution) + News paper	7.18	8.62	10.06	10.13	10.20
T_6 - Neem leaf extract (50% Solution) + News paper	7.10	8.52	9.93	10.01	10.08
T_7 - Moringa leaf extract (100% Solution) + News paper	6.29	7.55	8.80	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	6.22	7.47	8.71	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	6.18	7.41	8.65	*	*
Mean	6.58	7.89	9.39	9.79	10.21
SEm (±)	0.09	0.12	0.13	0.14	0.07
CD (5%)	0.27	0.34	0.39	0.41	0.21

***** End of shelf life

Table 5: Effect of various bio-extracts and packaging material on non-reducing sugar of Papaya.

Treatment details	Non-reducing sugar (%)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	1.35	1.62	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	1.69	2.03	2.37	2.39	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	1.67	2.01	2.34	2.36	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	1.66	1.99	2.32	2.34	*
T_4 - Neem leaf extract (100% Solution) + News paper	1.82	2.19	2.55	2.57	2.59
T_5 - Neem leaf extract (75% Solution) + News paper	1.80	2.16	2.51	2.53	2.55
T_6 - Neem leaf extract (50% Solution) + News paper	1.77	2.13	2.48	2.50	2.52
T_7 - Moringa leaf extract (100% Solution) + News paper	1.57	1.89	2.20	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	1.56	1.87	2.18	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	1.54	1.85	2.16	*	*
Mean	1.64	1.97	2.35	2.45	2.55
SEm (±)	0.02	0.03	0.03	0.03	0.02
CD (5%)	0.06	0.08	0.09	0.09	0.05

***** End of shelf life

Table 6: Effect of various bio-extracts and packaging material on total sugar of Papaya.

Treatment details	Total sugar (%)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	6.74	8.09	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	8.46	10.15	11.84	11.93	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	8.37	10.04	11.72	11.80	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	8.29	9.95	11.61	11.69	*
T_4 - Neem leaf extract (100% Solution) + News paper	9.12	10.94	12.77	12.86	12.95
T_5 - Neem leaf extract (75% Solution) + News paper	8.98	10.78	12.57	12.66	12.75
T_6 - Neem leaf extract (50% Solution) + News paper	8.87	10.64	12.42	12.51	12.60
T_7 - Moringa leaf extract (100% Solution) + News paper	7.86	9.43	11.00	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	7.78	9.34	10.89	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	7.72	9.26	10.81	*	*
Mean	8.22	9.86	11.74	12.24	12.77
SEm (±)	0.12	0.15	0.18	0.16	0.05
CD (5%)	0.36	0.44	0.53	0.46	0.14

***** End of shelf life

Table 7: Effect of various bio-extracts and packaging material on taste and flavor of Papaya.

Treatment details	Taste and Flavor (Score out of 9)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	5.58	5.80	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	7.00	7.29	7.43	7.57	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	6.93	7.21	7.35	7.48	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	6.86	7.14	7.28	7.41	*
T_4 - Neem leaf extract (100% Solution) + News paper	7.55	7.85	8.00	8.16	8.23
T_5 - Neem leaf extract (75% Solution) + News paper	7.44	7.73	7.88	8.03	8.10
T_6 - Neem leaf extract (50% Solution) + News paper	7.34	7.64	7.79	7.93	8.01
T_7 - Moringa leaf extract (100% Solution) + News paper	6.51	6.77	6.90	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	6.44	6.70	6.83	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	6.39	6.65	6.78	*	*
Mean	6.81	7.08	7.36	7.76	8.11
SEm (±)	0.09	0.10	0.11	0.11	0.06
CD (5%)	0.28	0.30	0.32	0.33	0.17

***** End of shelf life

Table 8: Effect of various bio-extracts and packaging material on aroma of Papaya.

Treatment details	Aroma (Score out of 9)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	5.52	5.75	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	6.93	7.21	7.35	7.49	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	6.86	7.14	7.27	7.41	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	6.80	7.07	7.20	7.34	*
T_4 - Neem leaf extract (100% Solution) + News paper	7.48	7.77	7.92	8.07	8.15
T_5 - Neem leaf extract (75% Solution) + News paper	7.36	7.66	7.80	7.95	8.02
T_6 - Neem leaf extract (50% Solution) + News paper	7.27	7.56	7.71	7.85	7.93
T_7 - Moringa leaf extract (100% Solution) + News paper	6.44	6.70	6.83	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	6.38	6.63	6.76	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	6.33	6.58	6.71	*	*
Mean	6.74	7.01	7.28	7.69	8.03
SEm (±)	0.09	0.10	0.11	0.11	0.04
CD (5%)	0.27	0.29	0.31	0.32	0.13

***** End of shelf life

Table 9: Effect of various bio-extracts and packaging material on overall acceptability of Papaya.

Treatment details	Overall acceptability (Score out of 9)				
	3 days	6 days	9 days	12 days	15 days
T_0 - Control	5.72	5.83	*	*	*
T_1 - Aloe vera gel extract (100% Solution) + News paper	7.18	7.32	7.36	7.43	*
T_2 - Aloe vera gel extract (75% Solution) + News paper	7.11	7.24	7.28	7.35	*
T_3 - Aloe vera gel extract (50% Solution) + News paper	7.04	7.17	7.21	7.28	*
T_4 - Neem leaf extract (100% Solution) + News paper	7.75	7.89	7.94	8.01	8.03
T_5 - Neem leaf extract (75% Solution) + News paper	7.63	7.77	7.81	7.89	7.91
T_6 - Neem leaf extract (50% Solution) + News paper	7.53	7.67	7.72	7.79	7.81
T_7 - Moringa leaf extract (100% Solution) + News paper	6.68	6.80	6.84	*	*
T_8 - Moringa leaf extract (75% Solution) + News paper	6.61	6.73	6.77	*	*
T_9 - Moringa leaf extract (50% Solution) + News paper	6.56	6.68	6.72	*	*
Mean	6.98	7.11	7.30	7.62	7.92
SEm (±)	0.09	0.09	0.10	0.11	0.06
CD (5%)	0.26	0.28	0.30	0.31	0.18

***** End of shelf life

Conclusion

Coating papaya fruits with neem leaf extract, particularly T_4 - Neem leaf extract (100% solution) combined with newspaper, thereby extending shelf life up to 15 days. In contrast, control fruits (T_0) deteriorated rapidly, showing quick ripening and spoilage. Fruits treated with bio-extract coatings consistently demonstrated better postharvest quality and storability compared to untreated fruits. Among the treatments, T_4 (100% neem extract + newspaper) performed best in maintaining nutritional attributes such as TSS, acidity, and reducing, non-reducing, and total sugars, and was statistically comparable to T_5 (75% neem extract + newspaper) and T_6 (50% neem extract + newspaper). The control (T_0) consistently exhibited the lowest nutritional quality. Sensory evaluation also indicated that T_4 received the highest consumer preference, followed closely by T_5 and T_6, whereas T_0 scored the lowest due to poor taste, flavor and overall acceptability.

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