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Studies on the effect of different packaging materials and storage conditions on the shelf life of tamarind pulp (*Tamarindus indica* L.) variety no-263

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Abstract
The present investigation was undertaken to assess the storage behavior and shelf life of deseeded tamarind pulp (*Tamarindus indica* L.) variety No-263 packed in different packaging materials and stored under varying temperature conditions for a period of six months. The experiment was laid out in a Factorial Completely Randomized Design (FCRD). Three packaging materials (P_1-Polypropylene, P_2-Silver Foil, P_3-Vacuum) were combined with three storage conditions (C_1-Ambient, C_2-Refrigerated (10 °C), C_3-Deep Freeze (4 °C)) to form nine treatment combinations (T_1 to T_9). Observations were recorded at monthly intervals for six months for various quality parameters. The quality of the tamarind pulp declined progressively over the storage period. Treatment T_9 (Vacuum + Deep Freeze) consistently retained the highest pH (2.81) and Total Soluble Solids (TSS) (19.50%), while showing the minimum increase in acidity (8.60%). Conversely, T_1 (Polypropylene + Ambient) recorded the most rapid deterioration, with the lowest final pH (2.24), lowest TSS (15.80%), and maximum acidity (12.80%). In sensory evaluation, T_9 received the highest score (8.20), indicating excellent acceptability, compared to the lowest score of 6.20 for T_1. It can be concluded that combination of vacuum packaging and deep freeze storage T_9 proved significantly superior in preserving the physicochemical and sensory properties, providing maximum shelf-life extension and quality retention for tamarind pulp.

Keywords: *Tamarindus indica* L., tamarind pulp, packaging material, storage conditions

Introduction
Tamarind (*Tamarindus indica* L.), locally known as imli in Hindi, belongs to the family Leguminoceae and is a significant socio-economic horticultural crop in India. Originating in tropical Africa, it is widely cultivated in subtropical regions, including China, India, and Pakistan. The fruit pulp is valued commercially and medicinally, possessing a sweet-acidic taste largely due to its high content of tartaric acid and reducing sugars. However, the long-term storage of tamarind pulp presents a challenge. During storage, the firm brown pulp tends to darken, absorb moisture, soften, and undergo pectolytic degradation. The color may change from golden brown to dark black-brown, leading to a loss of quality and reduced consumer acceptance. Non-enzymatic oxidation (Maillard reaction) and enzymatic oxidation of phenols are primary causes of this quality loss (Kotecha and Kadam 2003) [2]. Therefore, there is a clear need for improved packaging technology to enhance storage stability, extend shelf life, and add value for stakeholders. This research was undertaken to study the impact of various flexible packaging materials and storage temperatures on the shelf life of tamarind pulp with the objectives:

1. To evaluate the effect of packaging material on the storage of tamarind pulp.
2. To study different physiological properties of tamarind pulp.

Materials and Methods
The investigation was conducted at the Fruit Research Station, Himayat Bagh, Chhatrapati Sambhajinagar, Maharashtra, India, during the period of 2024-2025.The experiment was set up using a Factorial Completely Randomized Design (FCRD). The study utilized two factors, each with three levels, resulting in nine treatment combinations T_1 to T_9, replicated three

times. Factor P (Packaging Materials): P_1- Polypropylene, P_2- Silver Foil, P_3- Vacuum packaging. Factor C (Storage Conditions): C_1-Ambient Temperature, C_2- Refrigerated (10 °C), C_3- Deep Freeze (4 °C). Deseeded tamarind pulp (variety No-263) was processed and packed according to the treatment combinations. Observations for various parameters were recorded at monthly intervals for six months. The various physio-chemical properties were evaluated. analysis procedures were followed as per standard methods (e.g., acidity determination as per Ranganna 1986) [4]. Sensory evaluation was performed by a panel of 10 untrained judges using a 9-point Hedonic scale for colour, appearance, flavor, and overall acceptability forming nine treatment combinations replicated thrice.

Results and Discussion

The results showed a highly significant interaction effect between packaging material and storage condition on all parameters throughout the six-month storage period.

pH

The pH of the tamarind pulp showed a decreasing trend over the storage period. The highest final pH (at 180 days) was maintained by T_9 (Vacuum × Deep Freeze) at 2.81, which was statistically at par with T_8 (Vacuum × Refrigerated) (2.79) and T_6 (Silver Foil × Deep Freeze) (2.80). The lowest pH (2.24) was observed in T_1 (Polypropylene × Ambient). The decline in pH is primarily attributed to fermentation and the formation of organic acids during storage. Vacuum-packed and deep-frozen samples retained higher pH due to restricted microbial growth and a lower metabolic rate, which slows down fermentation. This preservation effect is in agreement with the work of Nagalakshmi and Chezhiyan (2004) [3], who reported extended shelf life under refrigerator and vaccum seal conditions.

Total Soluble Solids (TSS)

TSS content showed a gradual decrease across all treatments during storage. The maximum TSS (19.5%) at 180 days was recorded in T_9 (Vacuum × Deep Freeze), while the minimum TSS (15.8%) was in T_1 (Polypropylene × Ambient). The decrease in TSS is generally consistent with the conversion of complex carbohydrates into soluble sugars and moisture loss.

Acidity

A gradual increase in titratable acidity was observed. The maximum acidity (12.80%) was recorded in T_1 at the end of 180 days, and the minimum (8.60%) was in T_9. The increase in acidity is due to the accumulation of organic acids produced during microbial and enzymatic degradation.

Sensory Evaluation

Sensory parameters, including color, flavor, and overall acceptability, deteriorated over time in all treatments. T_9 (Vacuum + Deep Freeze) consistently maintained the highest scores, receiving an overall acceptability score of 8.20 (Excellent acceptability), whereas T_1 (Polypropylene + Ambient) scored the lowest at 6.20. This difference is largely due to T_1 being most susceptible to increased microbial and enzymatic activity, leading to rapid deterioration. (Amerine, *et.al* 1965) [1]

Table 1: Effect of Packaging materials and storage conditions on pH of Tamarind pulp

Treatments	pH					
	30 days	60 days	90 days	120 days	150 days	180 days
Packaging materials						
P_1	2.83	2.78	2.72	2.66	2.59	2.51
P_2	2.83	2.81	2.78	2.76	2.73	2.69
P_3	2.83	2.80	2.77	2.74	2.71	2.67
S.E. ±	0.013	0.013	0.013	0.013	0.013	0.013
CD at 1%	0.039	0.039	0.039	0.039	0.039	0.039
Storage condtions						
C_1	2.83	2.75	2.66	2.58	2.49	2.39
C_2	2.83	2.81	2.78	2.76	2.72	2.69
C_3	2.83	2.83	2.83	2.82	2.81	2.80
S.E. ±	0.013	0.013	0.013	0.013	0.013	0.013
CD at 1%	0.039	0.039	0.039	0.039	0.039	0.039
Treatments						
T_1	2.83	2.68	2.54	2.46	2.36	2.24
T_2	2.83	2.78	2.75	2.72	2.69	2.65
T_3	2.83	2.71	2.68	2.57	2.42	2.29
T_4	2.83	2.80	2.73	2.68	2.63	2.59
T_5	2.83	2.82	2.78	2.75	2.71	2.68
T_6	2.83	2.83	2.82	2.81	2.81	2.80
T_7	2.83	2.83	2.80	2.83	2.78	2.71
T_8	2.83	2.83	2.83	2.81	2.81	2.79
T_9	2.83	2.83	2.83	2.83	2.82	2.81
S.E. (me) ±	0.022	0.022	0.022	0.022	0.022	0.022
CD at 1%	0.065	0.065	0.065	0.065	0.065	0.065

Table 2: Effect of Packaging materials and storage conditions on TSS (%) of Tamarind pulp

Treatments	TSS (%)					
	30 days	60 days	90 days	120 days	150 days	180 days
Packaging materials						
P_1	19.6	19.2	18.8	18.4	18.0	17.6
P_2	19.6	19.5	19.4	19.2	19.1	19.0
P_3	19.6	19.4	19.2	19.0	18.8	18.6
S.E. ±	0.06	0.07	0.09	0.10	0.11	0.13
CD at 1%	0.18	0.21	0.27	0.30	0.34	0.38
Storage condtions						
C_1	19.6	19.0	18.4	17.8	17.3	16.8
C_2	19.6	19.4	19.1	18.9	18.7	18.4
C_3	19.6	19.6	19.6	19.5	19.4	19.3
S.E. ±	0.06	0.07	0.09	0.10	0.11	0.13
CD at 1%	0.18	0.21	0.27	0.30	0.34	0.38
Treatments						
T_1	19.6	18.9	18.1	17.2	16.5	15.8
T2	19.6	19.0	18.5	17.9	17.4	16.9
T_3	19.6	19.1	18.6	18.2	17.9	17.6
T_4	19.6	19.3	19.0	18.6	18.2	17.9
T_5	19.6	19.5	19.2	18.9	18.6	18.3
T_6	19.6	19.5	19.4	19.2	19.0	18.8
T_7	19.6	19.5	19.3	19.3	19.2	19.0
T_8	19.6	19.6	19.6	19.5	19.4	19.3
T_9	19.6	19.6	19.6	19.6	19.6	19.5
S.E. (me) ±	0.10	0.12	0.14	0.16	0.18	0.21
CD at 1%	0.30	0.36	0.43	0.49	0.55	0.64

Table 3: Effect of Packaging materials and storage conditions on Acidity (%) content of Tamarind pulp

Treatments	Acidity (%)					
	30 days	60 days	90 days	120 days	150 days	180 days
Packaging materials						
P_1	8.00	8.75	9.40	10.05	10.70	11.30
P_2	8.00	8.25	8.50	8.75	9.00	9.25
P_3	8.00	8.55	9.05	9.50	9.95	10.35
S.E. ±	0.09	0.10	0.11	0.12	0.14	0.16
CD at 1%	0.27	0.30	0.33	0.36	0.42	0.48
Storage conditions						
C_1	8.00	8.90	9.80	10.65	11.50	12.30
C_2	8.00	8.45	8.90	9.30	9.75	10.15
C_3	8.00	8.20	8.30	8.40	8.50	8.60
S.E. ±	0.09	0.10	0.11	0.12	0.14	0.16
CD at 1%	0.27	0.30	0.33	0.36	0.42	0.48
Treatments						
T_1	8.00	9.10	10.15	11.10	12.00	12.80
T2	8.00	8.85	9.60	10.35	11.05	11.70
T_3	8.00	8.75	9.50	10.15	10.80	11.40
T_4	8.00	8.60	9.20	9.75	10.30	10.80
T_5	8.00	8.45	9.00	9.55	10.10	10.60
T_6	8.00	8.30	8.80	9.30	9.75	10.20
T_7	8.00	8.55	8.85	9.15	9.40	9.65
T_8	8.00	8.35	8.55	8.75	8.95	9.10
T_9	8.00	8.20	8.30	8.40	8.50	8.60
S.E. (me) ±	0.15	0.17	0.19	0.21	0.24	0.27
CD at 1%	0.45	0.51	0.57	0.63	0.72	0.81

Table 4: Effect of Packaging materials and storage conditions on Sensory Evaluation of Tamarind pulp

Treatment combination	Parameters			
	Colour and appearance	Flavour	Taste	Overall acceptability
T_1	5.80	6.50	6.30	6.20
T2	6.00	6.80	6.60	6.50
T_3	6.20	7.00	6.90	6.80
T_4	6.80	7.50	7.30	7.20
T_5	7.00	7.70	7.50	7.40
T_6	7.20	7.80	7.70	7.60
T_7	7.30	8.00	8.00	7.80
T_8	7.50	8.30	8.20	8.00
T_9	7.70	8.50	8.40	8.20

Conclusion

The present investigation clearly demonstrated that the quality of tamarind pulp declined progressively over the six months of storage, with the rate of deterioration significantly influenced by the packaging material and storage condition.

Vacuum packaging P_3 was significantly superior among packaging materials in preserving the pulp's physicochemical and sensory attributes.

Deep freeze storage C_3 was the most effective storage condition in minimizing quality degradation.

The combined treatment T_9 (Vacuum + Deep Freeze) consistently outperformed all other combinations across all parameters, indicating maximum shelf-life extension and quality retention.

T_1 (Polypropylene + Ambient) showed the worst performance, with rapid deterioration due to increased exposure to oxygen and fluctuating temperature.

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