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INFLUENCE OF RIPYLENE-6 AND COLD CHAMBER STORAGE ON RIPENING BEHAVIOUR AND QUALITY ATTRIBUTES OF MANGO FRUITS

Pravin Dalavi[1*], Quraazah Akeemu Amin[2], Towseef A. Wani[2], Shahnaz Parveen[2], Riddheshwar Shinde[2], Dnyaneshwar Ingole[3], Karthikeyan P.[2] and Rahul Ranveer[4]

[1]Post-Harvest Manager, New Leaf Dynamic Technologies Private Limited, Shivajinagar- 411003, Pune, Maharashtra, India.
[2]Division of Food Science and Technology, SKUAST-K, India.
[3]Kay Bee Bio Organic Pvt. Ltd. Phaltan, Pune, India.
[4]PGIPHM, Roha, India.
*Corresponding author E-mail: pravindalavi98@gmail.com
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ABSTRACT

The present study was conducted to evaluate the effect of Ripylene-6 and cold chamber storage on ripening and quality parameters of mango fruits under different conditions. Three storage systems were used, namely ambient, cold chamber storage without Ripylene-6 (22°C and 90% RH), and cold chamber storage with Ripylene-6 (22°C and 90% RH). The observations on firmness, total soluble solids (TSS), pH, titrable acidity, physiological loss in weight (PLW), rot percentage, and colour values (L*, a*, b*) were recorded at regular intervals during ripening. The results showed that Ripylene-6-treated mangoes ripened faster and more uniformly compared with other treatments. Firmness and acidity were decreased, whereas TSS, pH, and colour values were increased during ripening. The minimum PLW and rot percentage were observed in Ripylene-6-treated fruits under controlled conditions. The study concluded that Ripylene-6 combined with cold chamber storage improved ripening uniformity, colour development, fruit quality, and shelf life of mango fruits.
***Keywords* :** Kesar, Mango ripening, Ripylene-6, Cold chamber, Post-harvest quality.

Introduction

Mango (*Mangifera indica* L.), popularly known as the "King of Fruits," is one of the most important tropical fruits cultivated worldwide due to its excellent flavor, aroma, nutritional value, and high commercial significance. India is the largest producer of mangoes globally and contributes nearly 40–45% of total world production. Mango is the most extensively cultivated fruit crop throughout India and stands first in mango production in the world. During 2023–24 India produced 21.82 million MT of mangoes from over 2 million hectares contributing 40% of global production (Statista, 2023). Among the numerous commercial cultivars grown in India, Kesar Mango is considered one of the finest table varieties because of its attractive saffron-colored pulp, pleasant aroma, high sweetness, and superior processing quality. The cultivar originated from the Gir region of Gujarat and has gained remarkable popularity in both domestic and export markets. Kesar mango is widely preferred for fresh consumption as well as for processing into pulp, juice, nectar, candies, ice cream, and other value-added products because of its rich flavor and high Total Soluble Solids (Kad *et al.,* 2017). Kesar mango is a climacteric fruit, which means it continues to ripen after harvest through increased respiration and ethylene production. Ripening is a complex physiological and biochemical process involving transformation of starch into sugars, degradation of chlorophyll pigments, development of carotenoids, reduction in acidity, softening of fruit tissues, and development of characteristic aroma and flavor compounds. During ripening, important quality parameters such as TSS, sugar content, firmness, acidity, and peel color undergo significant changes. The fruit changes from green to yellow-orange due to chlorophyll degradation and carotenoid synthesis (Dutta *et al.,* 2021). Traditionally, mango ripening occurred naturally under ambient conditions. However, natural ripening often results in non-uniform color development, inconsistent texture, uneven sweetness, and substantial postharvest losses.

Calcium carbide (CaC_2) is a harmful fruit ripening chemical that releases acetylene gas. It can reduce oxygen supply to the brain and may cause headache, dizziness, weakness, vomiting, stomach irritation, skin damage, and difficulty in swallowing. Industrial-grade calcium carbide may also contain toxic arsenic and phosphorus impurities which are dangerous to human health. Ethylene glycol ($C_2H_6O_2$) is another harmful chemical that may damage the kidneys if consumed in high amounts. Ethylene (C_2H_4) and methyl jasmonate ($C_{13}H_{20}O_3$) are safer ripening agents because they are less toxic and help fruits ripen naturally, although they are more expensive. Ethephon ($C_2H_6ClO_3P$) is also considered safe when used at recommended low concentrations and has no major harmful effects on human health (Islam *et al.,* 2016).

Ethylene gas plays a crucial role in initiating physiological and biochemical changes during ripening. It stimulates respiration and activates enzymes responsible for converting starch into sugars, resulting in sweeter fruits. Ethylene also accelerates chlorophyll degradation and carotenoid synthesis, producing desirable colour development such as green to yellow or orange transition in mangoes and bananas. In addition, it promotes softening of fruit tissues through breakdown of cell wall components like pectin, improving texture and eating quality. Ethylene further enhances aroma and flavour compound production, contributing to consumer acceptability. Controlled ethylene exposure ensures more uniform ripening across fruit lots, reducing uneven maturity and improving commercial value (Kader, 2002).

Ethylene gas is considered a safer and more scientific ripening agent than harmful chemicals such as calcium carbide and excessive acetylene because ethylene is a natural plant hormone produced by fruits during normal ripening. It stimulates natural biochemical processes including color development, softening, aroma formation, and sugar accumulation without leaving highly toxic residues when used at recommended concentrations. In contrast, chemicals like calcium carbide may contain harmful impurities such as arsenic and phosphorus, which are associated with health risks including neurological disorders, respiratory irritation, gastrointestinal problems, hormonal imbalance, and potential carcinogenic effects (Hussain *et al.,* 2024; Maduwanthi & Marapana, 2021). The Food Safety and Standards Authority of India (FSSAI) permits controlled ethylene gas application up to 100 ppm for commercial fruit ripening because it mimics the fruit's natural ripening mechanism. However, calcium carbide is banned in India due to its toxic nature and associated health hazards. Ethylene gas also influences sensory attributes including flavor, aroma, appearance, and consumer acceptability. Controlled ripening promotes development of characteristic volatile compounds responsible for the unique aroma of Kesar mango. Studies have shown that mangoes exposed to ethylene gas for 18 hours exhibited better sensory quality, attractive peel color, desirable sweetness-acidity balance, and higher overall acceptability scores compared to untreated fruits.

Ripylene-6 is a commercial fruit ripening gas mixture widely used in ripening chambers for climacteric fruits such as mango, banana, papaya, and tomato. The formulation generally contains approximately 5% ethylene gas (C_2H_4) and 95% nitrogen gas (N_2). Ethylene is a naturally occurring plant hormone responsible for regulating fruit ripening processes, while nitrogen acts as an inert carrier gas that helps maintain a safe and controlled concentration of ethylene during application. The use of controlled ethylene treatment promotes uniform ripening and improves market quality without leaving harmful chemical residues on fruits (Chemtron Science Laboratories Pvt. Ltd., 2023).

Nitrogen present in Ripylene-6 serves mainly as a balancing and carrier gas. Since concentrated ethylene is highly reactive, nitrogen dilutes the ethylene concentration to safe operating levels and facilitates uniform gas distribution inside ripening chambers. This controlled atmosphere improves ripening efficiency and minimizes handling risks. Commercial ripening systems using ethylene-based formulations are preferred over hazardous chemicals such as calcium carbide because ethylene mimics natural fruit physiology and is considered safer when used according to recommended protocols (Watkins, 2006).

Ripylene-6 is selected for mango ripening because it is an ethylene-releasing ripening agent that provides safe, uniform, and controlled ripening. Ethylene is a natural plant hormone responsible for initiating physiological and biochemical changes such as colour development, softening, sugar accumulation, aroma formation, and reduction in acidity. Ripylene-6 helps achieve uniform ripening of mangoes within a shorter duration while maintaining better fruit quality compared with harmful chemicals like calcium carbide. It is widely preferred in commercial ripening chambers because it produces consistent ripening, improves market appearance, and reduces postharvest losses.

Studies on Kesar mango showed that ethylene treatment enhanced total soluble solids (TSS), improved colour, reduced firmness gradually, and maintained better eating quality (Kad *et al.,* 2017).

Cold chamber storage is important because low-temperature and high-relative-humidity conditions slow down respiration, moisture loss, microbial growth, and senescence of mango fruits. Proper cold storage maintains fruit firmness, reduces physiological loss in weight (PLW), and extends shelf life during transportation and marketing. However, excessively low temperatures may suppress ethylene biosynthesis and cause chilling injury in mangoes. Research showed that storage at chilling temperature (5°C) reduced ethylene production, ACC oxidase activity, and normal ripening behaviour in mango fruits. Therefore, mangoes are generally stored at safer temperatures around 12–15°C before ripening (Nair *et al.,* 2002). The combined effect of Ripylene-6 and cold chamber storage is highly beneficial for commercial mango handling. Cold storage delays over-ripening and preserves fruit quality during storage, while Ripylene-6 treatment initiates uniform ripening at the desired marketing stage. This combination improves colour development, sweetness, texture, shelf life, and consumer acceptability. Ethylene-induced ripening followed by controlled storage conditions also helps reduce wastage and maintain better biochemical quality. Research on modified atmosphere packaging and ethylene treatments reported improved fruit quality, enhanced TSS, better sugar accumulation, and prolonged shelf life when ethylene ripening was combined with controlled storage systems (Singh & Janes, 2000).

Therefore, it is important for optimizing ripening conditions such as ethylene concentration, exposure duration, temperature, and humidity in order to achieve maximum fruit quality and shelf life. Understanding the biochemical and physiological changes during ripening can help develop improved postharvest handling technologies and reduce losses during storage and marketing. Such studies will be valuable for enhancing export quality, increasing farmer profitability, and strengthening the mango processing industry (Kad *et al.,* 2017).

The quality parameters of ripened mango fruits were evaluated using standard analytical methods. Total Soluble Solids (TSS) were determined using a digital hand refractometer and the results were expressed as °Brix. The pH of mango pulp was measured using a calibrated digital pH meter. Titratable acidity was estimated by titrating a known quantity of mango juice against standardized 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator, and the results were expressed as percentage citric acid. Fruit firmness was measured using a digital fruit firmness tester (penetrometer) by applying pressure to the peeled fruit surface and recording the force required for penetration. All measurements were carried out at regular intervals during the ripening period to assess changes in fruit quality.

Materials and Methods

Mango fruits were harvested during the early morning hours, preferably between 7:00 AM and 10:00 AM (Temp. 28°C and 55% RH) in 2 April 2024, when the field temperature was low and the fruits remained fresh with minimum moisture loss. Harvesting was avoided during hot afternoon conditions because high temperature increased respiration rate, sap burn, and postharvest deterioration. Mature mangoes were carefully harvested with stalks attached to reduce latex injury and mechanical damage.

After harvesting, the fruits were kept under shade and transported quickly to the cold chamber or packhouse in clean plastic crates to avoid bruising and compression damage. During transportation, the temperature was maintained around 13–15°C with 90% relative humidity to preserve freshness and reduce physiological weight loss. Gentle handling during loading and unloading was followed because mangoes were highly sensitive to impact injury.

At the packhouse, the fruits were sorted and graded based on maturity, size, colour, shape, and absence of diseases or physical defects. Damaged, diseased, and immature fruits were removed to ensure uniform ripening and better market quality. Pre-cooling was carried out before storage or ripening treatment. Mangoes were pre-cooled at 13–15°C for about 4–6 hours depending on fruit size and field heat. Pre-cooling removed field heat rapidly, slowed respiration, reduced moisture loss, maintained firmness, and improved shelf life and ripening uniformity during cold storage and ripening chamber operations. The New Leaf Dynamic Technologies Pvt. Ltd. cold room having dimensions of 22 ft × 12 ft × 9 ft, the total room volume was calculated as 2376 cubic feet. The room volume was then converted into cubic meters and found to be approximately 67.3 m^3. Generally, one Ripylene-6 bottle is recommended for about 40 m^3 chamber volume for proper mango ripening. Therefore, the number of Ripylene-6 bottles required for a 67.3 m^3 cold room was calculated by dividing 67.3 by 40, which gave 1.68 bottles. Hence, approximately 2 Ripylene-6 bottles were required to maintain the recommended ethylene concentration for uniform and effective mango ripening in the cold room.

Ripylene-6 was used for mango ripening in a sealed ripening chamber under controlled temperature and humidity conditions. Mature and healthy mango fruits were first sorted, graded, and pre-cooled before being placed uniformly inside plastic crates in the ripening chamber. The chamber temperature was maintained at about 22°C with 90% relative humidity for effective ripening. Based on the chamber volume, the required number of Ripylene-6 bottles was calculated and connected to the ripening system to release ethylene gas uniformly inside the chamber. The chamber was kept closed for about 24 hours to allow proper exposure of fruits to ethylene gas. After treatment, ventilation was provided to remove excess gas, and the fruits were kept under suitable storage conditions until uniform colour development, softening, and ripening were achieved. Ripylene-6 helped in obtaining uniform ripening, better colour development, improved flavour, and enhanced market quality of mango fruits. The pre-cooled mangoes were placed carefully in plastic crates (45 cm × 30 cm × 20 cm). The crates were then kept inside the cold room under controlled temperature and humidity conditions. At night, around 11:00 PM, Ripylene-6 was sprayed inside the cold room for mango ripening. The cold room was then kept closed for 24 hrs to allow uniform exposure of ethylene gas for effective and uniform ripening of mango fruits.

Three treatments were used for mango ripening during the experiment. In the first treatment, mango fruits were ripened under ambient room conditions without any controlled environment. In the second treatment, the fruits were kept in a cold chamber maintained at 22°C temperature and 90% relative humidity without Ripylene-6 treatment. In the third treatment, the mango fruits were placed in a cold chamber maintained at 22°C temperature and 90% relative humidity and were treated with Ripylene-6 for uniform ripening. The observations related to ripening and quality parameters were recorded at regular intervals during the storage period. Changes in colour, firmness, physiological loss in weight, total soluble solids, and overall fruit quality were observed and recorded for all treatments. The treatment details given below

Treatment No.	Treatment Details
T_1	Ambient condition ripening
T_2	Cold chamber without Ripylene-6 (22°C, 90% RH)
T_3	Cold chamber with Ripylene-6 (22°C, 90% RH)

Flow Chart of Mango Ripening Process in Cold Chamber

Mangoes are placed in plastic crates of 15 kg each

↓

Crates are stacked in the ripening chamber floor

↓

Set a temperature of 22°C and 90% RH)

↓

Sensor of data logger is inserted in the fruit in the middle crate to record fruit pulp temperature

↓

Chamber door is closed hermetically

↓

Once set temperature is achieved, Ethylene is released @ 100 ppm into the chamber

↓

After 24 hours of ethylene injection, door is opened to release CO_2

↓

After every 24 hours further, the door is opened for release of excess CO_2

↓

After achieving desired color, the fruit crates are removed from the chamber

(Rao *et al.,* 2020)

Result and Discussion

Market Specifications of Ripe Kesar Mango

Kesar mangoes are considered market-ready when they achieve optimum physicochemical and sensory quality suitable for consumer acceptance and commercial distribution. At this stage, fruits typically exhibit a firmness of 1.5–3.0 kg/cm², indicating adequate softness for consumption while retaining sufficient strength for handling and transportation. The Total Soluble Solids (TSS) content generally ranges from 20–22 °Brix, reflecting the high sweetness characteristic of ripe Kesar mangoes. The fruits possess a pH of 4.4–4.7 and a titratable acidity of 0.25–0.40% (as citric acid), providing a desirable balance between sweetness and acidity. The physiological loss in weight (PLW) is usually maintained within 6–10% indicating acceptable moisture loss during ripening and storage. Furthermore, rot or decay incidence should ideally remain below 5% and generally not exceed 10% to ensure acceptable shelf life and marketability. Market-ready fruits also develop the characteristic saffron-yellow peel colour, deep orange pulp, pleasant aroma, and juicy texture that are highly preferred by consumers. These quality attributes are commonly used as indicators of optimum ripeness and commercial maturity in Kesar mango marketing and postharvest management studies Kad *et al.,* (2017).

Parameter	Optimum Range for Marketing
Firmness (Kg/Cm^2)	1.5–3.0
TSS (°B)	20–22
pH	4.4–4.7
Titratable Acidity	0.25–0.40
PLW (%)	6–10
Rot (%)	<5 % (acceptable), maximum 10 %

Table 1 : Changes in Firmness, TSS, pH and Acidity of Mango during Ripening under Different Treatments

Para-meters	Ambient condition									Cold Chamber without Ripylene-6								Cold Chamber with Ripylene-6				
	Days									Days								Days				
	0	2	4	6	8	10	12	14	Mean	0	2	4	6	8	10	12	Mean	0	2	4	6	Mean
Firmness (Kg/Cm^2)	7.84 ± 0.18	7.10 ± 0.22	6.20 ± 0.15	5.00 ± 0.27	3.90 ± 0.31	2.80± 0.24	1.30± 0.35	0.60± 0.20	4.34	7.94 ± 0.15	7.75 ± 0.18	7.35 ± 0.22	6.78 ± 0.24	5.75 ± 0.20	5.12 ± 0.32	4.70 ± 0.24	6.48	7.89 ± 0.31	6.20± 0.25	4.53± 0.18	3.2± 0.20	5.46
TSS (°B)	7.20 ± 0.16	8.00 ± 0.25	9.50 ± 0.19	11.8 ± 0.30	16.5 ± 0.34	20.20 ± 0.28	21.40 ± 0.36	22.30 ± 0.23	14.61	7.25 ± 0.12	7.8± 0.15	8.9± 0.18	10.5 ± 0.23	13.2 ± 0.32	15.5 ± 0.30	18.0 ± 0.35	11.59	7.29 ± 0.20	10.90 ± 0.23	15.30 ± 0.25	20.2 ± 0.31	13.42
pH	3.02 ± 0.17	3.15 ± 0.21	3.35 ± 0.18	3.60 ± 0.26	3.95 ± 0.29	4.30± 0.32	4.80± 0.35	5.10± 0.24	3.91	3.02 ± 0.22	3.10 ± 0.17	3.25 ± 0.13	3.45 ± 0.23	3.75 ± 0.27	4.10 ± 0.32	4.45 ± 0.25	3.59	3.02 ± 0.27	3.80± 0.16	4.22± 0.20	4.72 ± 0.26	3.94
Acidity (%)	3.75 ± 0.24	3.55 ± 0.20	3.42 ± 0.18	3..10 ± 0.15	2.82 ± 0.22	2.41± 0.26	1.90± 0.32	1.12± 0.22	2.76	3.56 ± 0.17	3.13 ± 0.19	2.75 ± 0.23	2.32 ± 0.20	1.88 ± 0.24	1.25 ± 0.23	0.89 ± 0.20	2.25	3.25 ± 0.23	2.52± 0.27	1.68± 0.23	0.48 ± 0.21	1.98

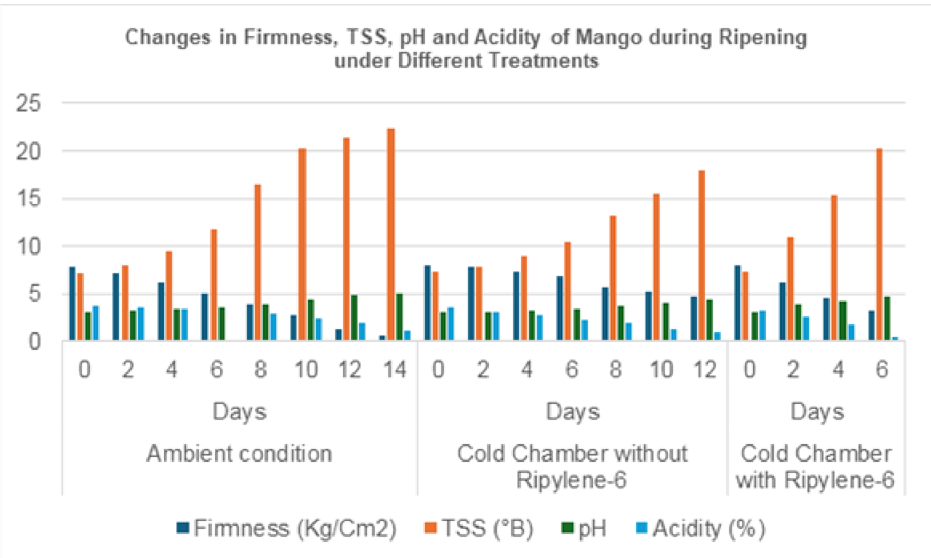


Fig. 1 : Changes in Firmness, TSS, pH and Acidity of Mango during Ripening under Different Treatments

During the ripening period, Table 1 and Fig 1 shows firmness of mango fruits was gradually reduced in all treatments. The firmness of Kesar mangoes decreased progressively during ripening under all storage conditions. Under ambient conditions, firmness declined from 7.84 kg/cm² at day 0 to 0.60 kg/cm² by day 14. In the cold chamber without Ripylene-6, the reduction in firmness was slower, decreasing from 7.94 kg/cm² to 4.70 kg/cm² over 12 days. In contrast, fruits stored in the cold chamber with Ripylene-6 showed accelerated softening, with firmness decreasing from 7.89 kg/cm² at day 0 to 3.20 kg/cm² by day 6, indicating faster ripening. The total soluble solids (TSS) content increased continuously throughout the ripening period. Under ambient conditions, TSS increased from 7.20 °Brix to 22.30 °Brix by day 14. In the cold chamber without Ripylene-6, TSS increased gradually from 7.25 °Brix to 18.00 °Brix over 12 days.

However, fruits treated with Ripylene-6 in the cold chamber exhibited a rapid increase in TSS from 7.29 °Brix to 20.20 °Brix within 6 days, demonstrating enhanced ripening and sugar accumulation. The pH of the fruits increased during ripening under all treatments. Under ambient conditions, pH rose from 3.02 to 5.10 during 14 days of storage. In the cold chamber without Ripylene-6, pH increased gradually from 3.02 to 4.45 by day 12. Fruits exposed to Ripylene-6 in the cold chamber showed a faster increase in pH, reaching 4.72 by day 6 from an initial value of 3.02. Titratable acidity decreased steadily as ripening progressed. Under ambient conditions, acidity declined from 3.75% to 1.12% during 14 days of storage. In the cold chamber without Ripylene-6, acidity decreased from 3.56% to 0.89% by day 12. Similarly, fruits stored in the cold chamber with Ripylene-6 exhibited a rapid reduction in acidity from 3.25% to 0.48% within 6 days. The decrease in acidity, accompanied by increases in TSS and pH, indicated the conversion of organic acids into sugars and other metabolites during the ripening process.

Similarly, pH values were increased gradually, whereas acidity percentage was decreased throughout the ripening period in all treatments. The fastest reduction in acidity and quickest ripening were observed in the cold chamber with Ripylene-6 treatment. During the ripening period, firmness of mango fruits was gradually decreased in all treatments due to the degradation of protopectin into soluble pectin and the breakdown of cell wall structure. The fastest reduction in firmness was observed in the cold chamber with Ripylene-6 treatment, which indicated accelerated ripening because ethylene stimulated the activity of softening enzymes such as polygalacturonase and pectin methyl esterase. Similar findings were reported by Kad *et al.,* (2017), who observed rapid softening of Kesar mango fruits under ethylene treatment. Hussain *et al.,* (2024) also reported that ethylene-ripened mangoes showed faster softening and better texture compared with chemically ripened fruits. Total soluble solids (TSS) were increased continuously during the ripening period in all treatments. The increase in TSS occurred because stored starch was hydrolyzed into simple sugars such as glucose, fructose, and sucrose during ripening. The highest and fastest increase in TSS was observed in Ripylene-6-treated fruits due to enhanced ethylene action and faster metabolic conversion of carbohydrates into sugars. Similar increases in TSS during ethylene-induced ripening were reported by Zhang *et al.* (2024), Chowdhury *et al.* (2025) and Singh and Janes (2000), who found that ethylene treatment accelerated sugar accumulation and improved sweetness in mango fruits. The pH values were increased gradually throughout the ripening period. The increase in pH was mainly due to the degradation of organic acids and reduction in titratable acidity during respiration and ripening processes. Ripylene-6-treated mangoes showed a more rapid increase in pH because ethylene accelerated biochemical and metabolic activities. Similar observations were reported by Hussain *et al.* (2024), who found increasing pH values during ethylene-mediated mango ripening. Acidity percentage was decreased progressively in all treatments during storage and ripening. Organic acids are utilized as respiratory substrates during fruit metabolism; therefore, acidity decreased as ripening advanced. The greatest reduction in acidity was observed in Ripylene-6-treated fruits due to enhanced respiration and ethylene-induced ripening activity. Similar results were reported by Kad *et al.* (2017) and Zhang *et al.* (2024), who observed significant reductions in acidity during mango ripening under ethylene treatment.

Table 2 : Changes in Colour Values *(L*, a**, b*) of Mango during Ripening under Different Treatments

Parameters (Colour values)	**Ambient condition**									**Cold Chamber without Ripylene-6**								**Cold Chamber with Ripylene-6**				
	Days									**Days**								**Days**				
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**Mean**	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**Mean**	**0**	**2**	**4**	**6**	**Mean**
L*	48.42 ± 0.78	49.80 ± 0.75	51.60± 0.56	54.20± 0.65	57.10± 0.74	60.20± 0.66	63.50± 0.68	65.80± 0.72	56.32	48.42 ± 0.76	49.10 ± 0.70	50.20± 0.67	52.80± 0.79	55.50± 0.82	58.90± 0.69	61.20± 0.85	53.73	48.42 ± 0.69	56.98± 0.79	61.32± 0.71	66.02± 0.77	58.19
a*	-12.28 ± 0.55	-10.50 ± 0.64	-7.20 ± 0.69	-2.50 ± 0.62	3.80 ± 0.72	9.50 ± 0.80	14.80± 0.61	17.50± 0.67	1.64	-12.28 ± 0.59	-11.20 ± 0.66	-9.10 ± 0.63	-5.40 ± 0.69	-0.50 ± 0.76	5.80 ± 0.85	10.90± 0.89	−3.11	-12.28 ± 0.73	-3.20 ± 0.82	11.80± 0.88	18.02± 0.92	3.59
b*	30.75 ± 0.66	33.20 ± 0.69	36.80± 0.72	41.50± 0.79	47.20± 0.81	53.50± 0.89	60.40± 0.75	66.50± 0.71	46.23	30.75 ± 0.61	32.20 ± 0.68	34.60± 0.73	38.80± 0.78	44.10± 0.67	49.80± 0.83	56.20± 0.91	40.92	30.75 ± 0.68	42.50± 0.95	55.12± 0.91	68.03± 0.97	**49.10**

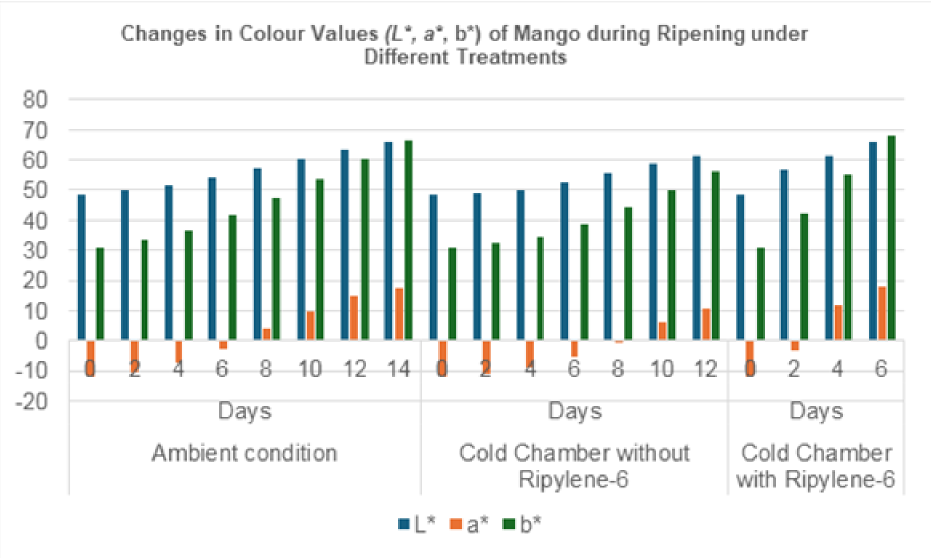


Fig. 2 : Changes in Colour Values *(L*, a**, b*) of Mango during Ripening under Different Treatments

During the ripening period, Table 2 and Fig 2 shows the L* colour values were gradually increased in all treatments, indicating an increase in fruit brightness and development of peel colour. Under ambient condition, L* values were increased from 48.42 to 65.80 by the 14th day, whereas in the cold chamber without Ripylene-6 they were increased from 48.42 to 61.20 by the 12th day. In the cold chamber with Ripylene-6 treatment, L* values were rapidly increased from 48.42 to 66.02 within 6 days, indicating faster and more uniform colour development. The a* values were also increased progressively during ripening. Initially, negative a* values indicated green colour, which gradually shifted toward positive values representing red-yellow ripened colour. Under ambient condition, a* values were increased from -12.28 to 17.50 by the 14th day, while in the cold chamber without Ripylene-6 they were increased from -12.28 to 10.90 by the 12th day. In Ripylene-6-treated fruits, a* values were rapidly increased from -12.28 to 18.02 within 6 days, indicating accelerated ripening and chlorophyll degradation. Similarly, b* values were increased continuously during storage and ripening, indicating the development of yellow colour pigments in mango fruits. Under ambient condition, b* values were increased from 30.75 to 66.50 by the 14th day, whereas in the cold chamber without Ripylene-6 they were increased from 30.75 to 56.20 by the 12th day. In the Ripylene-6-treated fruits, b* values were rapidly increased from 30.75 to 68.03 within 6 days, which showed enhanced yellow colour development and uniform ripening under ethylene treatment.

During the ripening period, the L* values were gradually increased in all treatments, indicating an increase in fruit brightness and peel colour development. The highest increase in L* values was observed in Ripylene-6-treated fruits, which indicated faster and more uniform ripening under ethylene exposure. The increase in brightness occurred due to chlorophyll degradation and development of carotenoid pigments during ripening. Similar findings were reported by Kad *et al.* (2017), who observed improved peel colour and brightness in ethylene-treated Kesar mangoes. Burondkar *et al*. (2018), Pujari *et al.* (2018) and Hussain *et al.* (2024) also reported that ethylene-ripened mangoes showed better colour development and visual appearance compared with untreated fruits. The a* values were increased progressively during storage and ripening. Initially, negative a* values represented green colour due to chlorophyll pigments, which gradually shifted toward positive values indicating development of red-yellow ripened colour. The rapid increase in a* values observed in Ripylene-6-treated fruits indicated faster chlorophyll degradation and enhanced synthesis of carotenoids under ethylene treatment. Similar changes in a* colour values during mango ripening were reported by Zhang *et al.* (2024), who observed accelerated colour transition in ethylene-induced mango ripening. Singh and Janes (2000) also reported enhanced peel colour development under ethylene treatment and modified atmosphere conditions. Similarly, b* values were increased continuously in all treatments, indicating development of yellow pigments during ripening. The highest increase in b* values was observed in Ripylene-6-treated mangoes due to accelerated carotenoid accumulation and faster ripening process. Ethylene stimulated chlorophyll breakdown and carotenoid biosynthesis, resulting in attractive yellow-orange peel colour. Similar increases in b* values during mango ripening were reported by Hussain *et al.* (2024) and Kad *et al.* (2017), who found that ethylene treatment improved yellow colour intensity and uniformity in mango fruits.

Table 3 : Changes in Physiological Loss in Weight (PLW) and Rot Percentage of Mango during Storage and Ripening under Different Treatments

Parameters	Ambient condition									Cold Chamber without Ripylene-6								Cold Chamber with Ripylene-6				
	Days									Days								Days				
	0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**Mean**	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**Mean**	**0**	**2**	**4**	**6**	**Mean**
PLW (%)	0	5.22	9.2	11.4	13.5	15.3	17.1	18.20	12.27	0	2.5	4.3	6.1	8.6	10.2	12.3	7.17	0	3.2	6.3	8.23	5.91
Rot percentage	-	-	1	3	5	7	10	12	6.33	-	-	-	1	3	5	7	3.20	-	-	2	5	**3.50**

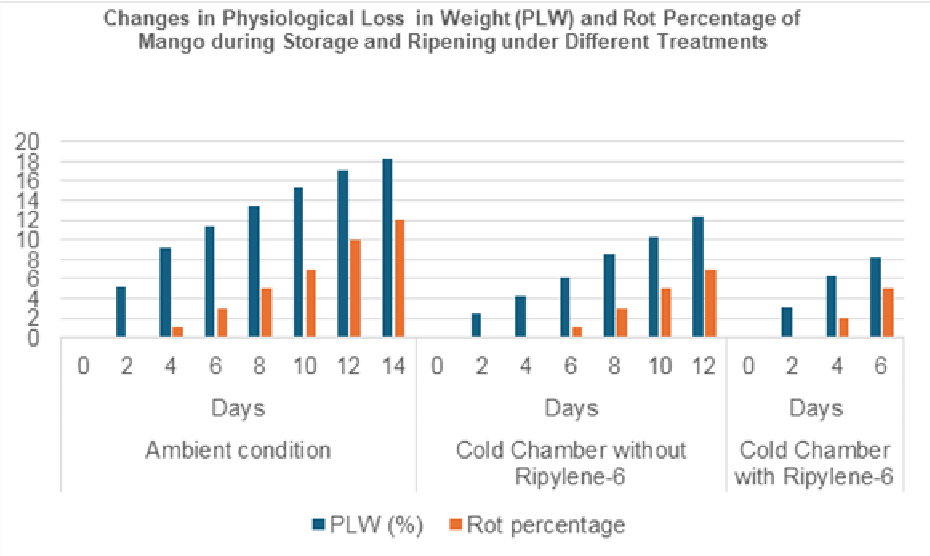
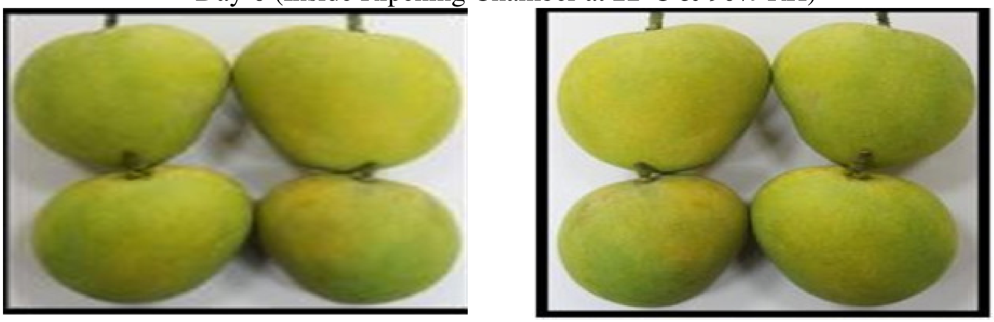


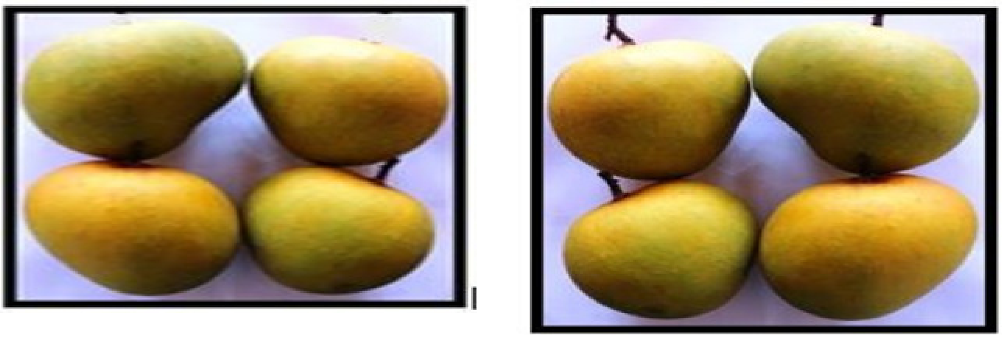
Fig. 3 : Changes in Physiological Loss in Weight (PLW) and Rot Percentage of Mango during Storage and Ripening under Different Treatments

During the storage and ripening period, Table 3 and Fig. 3 shows physiological loss in weight (PLW) was gradually increased in all treatments due to moisture loss and respiration. The physiological loss in weight (PLW) of Kesar mangoes increased progressively during storage under all ripening conditions. Under ambient conditions, PLW increased from 0% at day 0 to 18.20% by day 14. The highest rate of weight loss was observed under ambient storage due to increased respiration and transpiration. In the cold chamber without Ripylene-6, PLW increased more gradually from 0% to 12.30% over 12 days, indicating that low-temperature storage effectively reduced moisture loss. Fruits stored in the cold chamber with Ripylene-6 exhibited PLW values of 0%, 3.20%, 6.30%, and 8.23% on days 0, 2, 4, and 6, respectively. Although weight loss occurred during ripening, the cold chamber combined with Ripylene-6 maintained lower PLW than ambient storage while facilitating faster ripening. The incidence of fruit rot increased with storage duration in all treatments. Under ambient conditions, no rot was observed up to day 2, while rot incidence reached 1%, 3%, 5%, 7%, 10%, and 12% on days 4, 6, 8, 10, 12, and 14, respectively. In the cold chamber without Ripylene-6, fruits remained free from decay up to day 4, after which rot increased gradually from 1% on day 6 to 7% on day 12. In the cold chamber with Ripylene-6, no rot was observed up to day 2; however, rot incidence reached 2% on day 4 and increased to 5% by day 6. The increase in rot percentage during storage was associated with fruit softening and increased susceptibility to microbial infection. Nevertheless, cold storage delayed the onset and progression of decay compared with ambient storage, thereby extending the marketable life of the fruits.

Day-0 (Inside Ripening Chamber at 22°C & 90% RH)



Day-2 (Inside Ripening Chamber at 22°C & 90% RH)



Day-4 (Inside Ripening Chamber at 22°C & 90% RH)

Day-6 (Inside Ripening Chamber at 22°C & 90% RH)

Fig. 4: Interval Day-wise Photographs (Cold chamber with Ripylene-6 (22°C, 90% RH)

Fig. 5 : Photographs

The minimum rot percentage observed in the Ripylene-6-treated fruits indicated better ripening uniformity and reduced spoilage under controlled storage conditions. During the ripening and storage period, physiological loss in weight (PLW) was gradually increased in all treatments due to moisture loss through transpiration and respiration. The highest PLW was observed under ambient condition because fruits were exposed to higher temperature and lower relative humidity, which accelerated water loss and respiration rate. In contrast, lower PLW was observed in the cold chamber treatments because controlled temperature and high relative humidity reduced moisture evaporation and metabolic activity. The minimum PLW observed in Ripylene-6-treated fruits indicated that controlled ripening under cold chamber conditions helped maintain better fruit quality and reduced excessive weight loss. Similar findings were reported by Singh and Janes (2000), who observed lower weight loss in mango fruits stored under controlled atmosphere and ethylene treatment. Kad *et al.,* (2017) also reported reduced physiological loss in weight under controlled ethylene ripening conditions. Rot percentage was increased during the later stages of storage and ripening in all treatments due to fruit softening, increased respiration, and microbial activity. The highest rot percentage was observed under ambient condition because uncontrolled temperature and humidity accelerated senescence and fungal spoilage. Lower rot incidence was observed in cold chamber treatments because low temperature and controlled humidity slowed microbial growth and delayed deterioration. The minimum rot percentage observed in Ripylene-6-treated fruits indicated that uniform ripening and controlled environmental conditions reduced uneven ripening and spoilage. Similar observations were reported by Nair *et al.* (2002), who found that controlled storage conditions reduced decay and maintained mango quality during ripening. Hussain *et al.* (2024) also reported improved shelf life and lower spoilage in ethylene-ripened mangoes compared with uncontrolled ripening conditions.

Conclusion

The present study demonstrated that the combination of Ripylene-6 and cold chamber storage (22°C and 90% RH) significantly enhanced the ripening efficiency and quality of Kesar mangoes compared with ambient storage and cold chamber storage without Ripylene-6. Ripylene-6-treated fruits achieved market-ready maturity within 6 days, characterized by desirable firmness (3.20 kg/cm²), high total soluble solids (20.20 °Brix), optimum pH (4.72), reduced acidity (0.48%), and attractive saffron-yellow peel colour. The treatment also resulted in lower physiological loss in weight (8.23%) and acceptable rot incidence (5%), indicating better retention of fruit quality and shelf life. In contrast, ambient storage required a longer ripening period and was associated with excessive weight loss and higher decay, while cold chamber storage without Ripylene-6 delayed ripening and failed to attain optimum quality within the same period. The accelerated ripening observed in Ripylene-6-treated fruits was attributed to enhanced ethylene-mediated biochemical changes, including starch hydrolysis, organic acid degradation, cell wall breakdown, and carotenoid synthesis, which collectively improved sweetness, texture, and visual appeal.Overall, the findings confirm that Ripylene-6, when used under controlled cold chamber conditions, provides a rapid, uniform, and commercially effective ripening system for Kesar mangoes. This technology not only reduces ripening time but also improves marketability, minimizes postharvest losses, and ensures consistent fruit quality. Therefore, its adoption can be highly beneficial for mango producers, ripening facilities, and supply chains seeking to deliver superior-quality fruits to consumers while maximizing economic returns.

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