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Evaluation of packaging materials for enhancing the storage life of marigold flowers (*Tagetes erecta*)

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ABSTRACT

Among the various loose flower crops, marigold (*Tagetes erecta* L.) holds a prominent place among commercial crops. Its vibrant blooms are in high demand, but flowers are perishable, rendering them susceptible to significant post-harvest losses. Efforts to mitigate these losses will enhance the overall flower production, distribution to maximize its economic potential and to sustain valuable contribution for the industry. So, the present experiment on storage of marigold flowers was conducted during 2021 and 2022 at the ICAR- Indian Agricultural Research Institute, New Delhi with an objective to improve the shelf life of flowers by using different packaging materials. The results revealed that in marigold var. Pusa Basanti Gainda, maximum shelf life, high carotenoid content, minimum ion leakage, physiological loss in weight and enzyme activity were achieved in flowers packed in shrink-wrap and stored under low-temperature (6 ± 2^0C) conditions.

Keywords: Loose flowers, Marigold, Packaging, Shrink-wrap, Storage

Floriculture is a rapidly expanding global market, with India alone cultivating flowers on 322,000 ha producing 2,152000 tonnes of loose flowers and 82,8000 tonnes of cut flowers in 2021 (NHB 2021). Among these, marigold (*Tagetes erecta* L.) a member of family Asteraceae, stands out as an economically significant flower crop. It is cultivated for loose flowers, bedding, pot plants, essential oils and carotenoids. However, its perishability poses a challenge during glut periods in the market. One of the primary challenges in both cut and loose flower production and trade is their short post-harvest life. During flower senescence, various physiological and biochemical changes occur which includes ion leakage, metabolite transport, generation of reactive oxygen species, increased membrane fluidity, hydrolysis of proteins, nucleic acids, lipids and carbohydrates (Tripathi and Tuteja 2007).

Inefficient post-harvest handling practices results in significant flower losses during marketing, accounting for approximately 20 to 30% of losses (Jadhav 2018). One effective method for maintaining flower quality throughout the supply chain is proper packaging which not only reduces mechanical damage but also serves as a protective barrier between the flower's internal and external environments, but shields the flowers from ethylene and oxygen, by creating controlled microclimate inside the packaging (Krishnamoorthy 1990). This not only preserves the fresh and attractive appearance of the flowers but also helps to regulate market supply, preventing over saturation and ultimately boosting the income of growers, wholesalers and retailers.

The delicate and perishable nature of flowers demands specialized packing materials and advanced packaging technology to maintain their freshness over an extended period. Unlike chemical flower preservatives, which necessitate specific skills for solution preparation and flower treatment, various packaging materials are readily available, cost-effective, user-friendly and environmentally sustainable. Therefore, the study was carried out with the objective of improving the shelf life of marigold loose flowers by using different packaging materials.

MATERIALS AND METHODS

Plant material: African marigold cv. Pusa Basanti Gainda flowers were grown during 2021 and 2022 at the Research farm of the ICAR-Indian Agricultural Research Institute, New Delhi. The experiment consisted of 10 treatment combinations including 5 packaging materials, viz. HDPE bags (P_1), LDPE bags (P_2), shrink-wrap (P_3), butter paper bags (P_4), and muslin cloth bags/control (P_5); and two storage conditions: ambient (27±2°C), low-temperature (6±2°C). Marigold flowers were harvested in the morning in the month of March and were brought to

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the laboratory and 10 uniform sized flowers were packed in each packaging material and were stored both at ambient and low-temperature storage conditions. The observations were recorded for different morphological, physiological and biochemical parameters daily at ambient storage conditions while under low-temperature storage conditions at 4-days interval.

The observations were recorded for shelf life (days), spoilage (%), physiological loss in weight (%), ion leakage (%) as described by Sairam *et al.* (1997); total carotenoid content (mg/100 g) by Ranganna (1995); superoxide dismutase (SOD activity/mg protein/min) by method of Dhindsa *et al*. (1981); catalase activity (micromol/mg protein/min) as described by Aebi (1984); and guaiacol peroxidase activity (millimol/g FW/min) as described by Castillo *et al*. (1984).

RESULTS AND DISCUSSION

Shelf life (days): Data indicated that the shelf life of marigold loose flowers was significantly affected by packaging materials and storage conditions. Under ambient temperature conditions, maximum shelf life (4.83 days) was observed in shrink-wrap while a minimum (2.83 days) was observed under control. Similarly, under low-temperature conditions a maximum shelf life (16.33 days) was observed in shrink-wrap (P_3) while a minimum (8.66 days) was observed under control. It might be owing to the fact that the shrink-wrap created a protective barrier against moisture loss, contamination, and physical damage, maintaining balance between carbon dioxide and oxygen concentration and low respiration rate (Saidulu 2013). Similar results were observed by Singh *et al.* (2014), Panwar *et al.* (2020) and Belavanaki (2021).

Spoilage (%): Data depicts that after one-day storage at ambient temperature conditions, minimum spoilage (15.96%) occurred in flowers packed in butter paper bags (P_4) which was at par with 16.35% of flowers packed in HDPE bags and maximum spoilage (21.59%) was observed in control (P_5) (Fig. 1A). Storage of flowers 2nd and 3rd day resulted in minimum spoilage (29.52%, 41.90%), with shrink-wrap while maximum (39.13%, 54.44%) in muslin cloth bags.

Perusal of data (Fig. 1B) revealed that on the 4th day of storage, minimum spoilage (10.91%) was recorded in flowers packed in LDPE which was at par with flowers packed in shrink-wrap, while maximum (23.63%) was observed in butter paper bags. During 8th day, the minimum spoilage (21.69%) was observed in shrink-wrap, while the maximum (48.19%) was recorded in control. During the 12th day, the minimum spoilage (34.37%) was observed in shrink-wrap while the maximum (48.67%) was observed in flowers packed in LDPE bags (P_2). All the treatments were over after 15 days except the shrink-wrap where spoilage per cent was recorded up to 37.29 and 50.07% during 16th and 17th day, respectively. The minimum spoilage per cent of flowers indicates less number of damaged, wilted and rotten flowers. This positive effect may be attributed to the tight, sealed barrier of shrink-wrap around the flowers which limits the exchange of gases, particularly oxygen and ethylene might slower down the enzymatic reactions responsible for senescence (Thakur *et al.* 2017).

High relative humidity and reduced transpiration losses in the flowers packed in shrink-wrap and HDPE bags due to its antioxidant properties reduced the spoilage of flowers. The influences of intrinsic characteristics as well as external factors such as temperature, water activity, preservatives, packaging material and gaseous composition affect spoilage. Similar results were observed by Sharma *et al.* (2021) in marigold and Rakesh *et al*. (2022) in gaillardia.

Physiological loss in weight (PLW%): Data pertaining to PLW at ambient temperature conditions presented in Fig. 2(A) mentions that on the first day, minimum PLW (1.46%) was recorded in flowers packed in HDPE (P_1) which was at par with flowers packed in shrink-wrap while maximum (4.46%) was observed in muslin cloth bag. Similarly, during 2nd and 3rd day, minimum PLW was observed in shrink-wrapped flowers while the maximum was recorded in muslin cloth bags. All the treatments were over after 3 days except the shrink-wrapped packaged flowers which exhibited PLW of 9.31% on 4th day of storage.

Under low-temperature storage conditions, the minimum weight loss (1.57%) was recorded on 4th day (Fig. 2B) in flowers packed in shrink-wrap and was at par with HDPE bags while the maximum loss (4.12%) was observed in control. During the 8th day, the minimum PLW (2.77%) was observed in P_3, while the maximum (11.83%) was recorded in in muslin cloth bags. During 12th day, the minimum PLW (4.68%) was observed in flowers packed in butter paper bags, while the maximum (10.4%) was observed in LDPE bags. All the treatments were over after 15 days

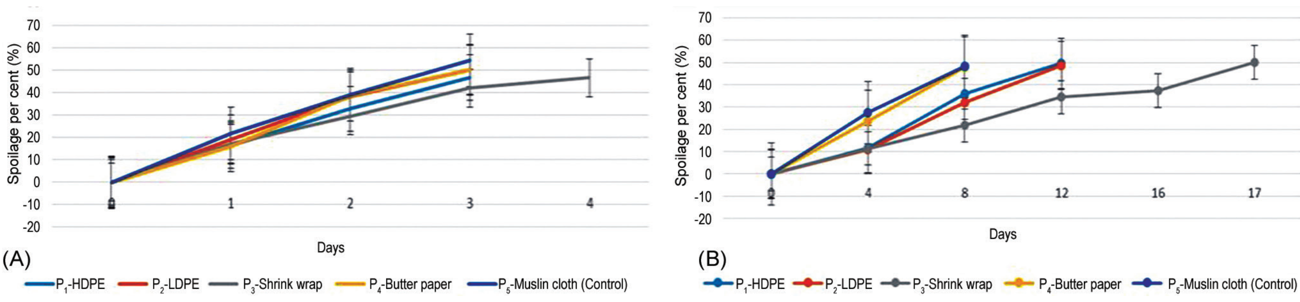

Fig. 1 Effect of packaging materials on spoilage (%) of loose marigold flowers: (A) under room temperature; (B) under low-temperature storage conditions.

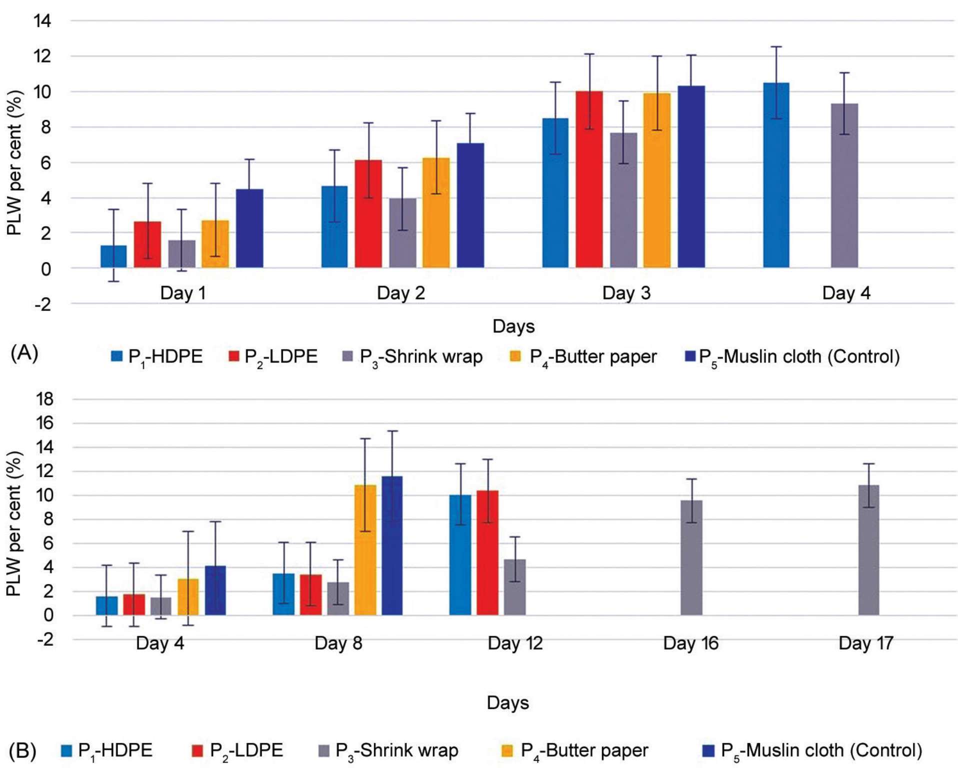

Fig. 2 Effect of packaging materials on PLW (%) of loose marigold flowers: (A) under room temperature; (B) under low-temperature storage conditions.
PLW, Physiological loss in weight.

except the shrink-wrap package in which PLW was found to be 9.5 and 10.8% on the 16th and 17th day, respectively.

Packaging maintains a higher humidity level, which slows down the process of moisture loss. Additionally, a balanced carbon dioxide and oxygen concentration also reduces the process of respiration (Bhowmik and Hulbert 1989). This might be the reason that shrink-wrap had the lowest recorded PLW during the entire storage period. Additionally, the cold storage restricted the rate of respiration, other enzymatic activity and decreased moisture content that had a significant impact on the PLW. Similarly, Bhattacharjee and De (2005) also explained that at lower temperatures, respiration reduces and the amount of ethylene produced by the flowers decreases which ultimately increases the flower quality and appearance. Similar were the findings of Lavanya *et al.* (2016) and Devi *et al.* (2017) in marigold, Yathindra *et al.* (2018) in jasmine, Archana *et al.* (2019) in tuberose flowers and Rakesh *et al.* (2022) in gaillardia.

Ion leakage (%): Data (Table 1) revealed that under ambient temperature conditions, on initial two days recorded minimum ion leakage (27.64%) and (30.05%) in flowers packed in shrink-wrap while the maximum 37.78 and 4.19% in control. During the third day, minimum ion leakage (31.58%) was observed in shrink-wrap whereas, the maximum (40.79%) was observed in LDPE. On 4th day, only the flowers packed in shrink-wrap left with 37.72 % ion leakage under ambient temperature conditions.

Under low-temperature, on 4th day, the minimum ion leakage (28.07%) was recorded in flowers packed in shrink-wrap and the maximum was (38.97%) observed in control (P_5). Similarly, on 8th day, minimum ion leakage (29.88%) was observed in (P_3), but the maximum (40.66%) was recorded in control. During 12th day, minimum ion leakage (35.29%) was observed in shrink-wrap while maximum (39.33%) was observed in LDPE bags. All the treatments were over after 15 days except shrink-wrap and on 16th and 17th day the ion leakage was found to be 37.99 and 40.08%, respectively. At the biochemical level, senescence is associated with changes in membrane fluidity and leakage of ions. Minimum ion leakage was observed in flowers packed in shrink-wrap under low-temperature compared to control, which might be due to low degree of membrane deterioration expressed as leakage of ions. Similar findings were reported by Pal *et al*. (2016) in marigold, Kumari *et al*. (2017) and Khongwir *et al.* (2018) in tuberose.

Super oxide dismutase (SOD Activity/mg protein/min): For SOD activity data (Table 1) revealed that under ambient temperature minimum during first day storage SOD activity (15.5 units) was recorded in flowers packed in HDPE bags and maximum (19.9) in control. During 2nd and 3rd day, minimum SOD (17.42 and 24.24) was observed in shrink-wrap while maximum was recorded in butter paper bags. On 4th day SOD activity of 23.19 units was recorded for the flowers packed in shrink-wrap.

Data with respect to storage under low-temperature conditions revealed that on 4th day, minimum (14.33) SOD activity was recorded in flowers packed in HDPE bags and maximum (18.73) in control. On 8th day, minimum (15.89) SOD was observed in shrink-wrap, while maximum (22.73) was recorded in muslin cloth bags. On 12th day, minimum (18.42) SOD was observed in shrink-wrap while maximum (21.87) was observed in LDPE bags. Shrink-wrap packaged flowers survived till 16th and 17th day having SOD Activity of 21.66 and 24.00 mg protein/min. This may be due to the accumulation of superoxide radicals in the floret tissue, caused by storage stress and disturbances in antioxidant balance. Similar results were observed by Jawaharlal *et al.* (2012) and Kumari *et al.* (2017).

Catalase activity (micromol/mg protein/min): Data (Table 2) revealed that on 1st, 2nd and 3rd day minimum catalase activity (0.65, 1.57 and 2.14 units) under ambient temperature conditions was recorded in flowers packed in

Table 1 Effect of packaging material and storage conditions on ion leakage and super oxide dismutase of marigold loose flower

Packaging material (P)	Ion leakage (%)											Super oxide dismutase (SOD Activity/mg protein/min)										
	Storage duration at room temperature (27±2°C)					Storage duration at low temperature (6±2°C)						Storage duration at room temperature (27±2°C)					Storage duration at low temperature (6±2°C)					
	0 day	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day	17^{th} day	0 day	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day	**17^{th} day**
P_1, HDPE	27.66	30.19	32.27	37.92	0.00	28.21	29.16	34.42	35.49	0.00	0.00	13.13	15.56	17.53	23.13	0.0	11.9	14.33	16.29	18.90	0.00	0.00
P_2, LDPE	28.66	31.18	33.27	38.91	0.00	30.08	31.03	36.29	39.33	0.00	0.00	11.64	16.02	18.12	23.10	0.0	10.41	14.78	14.79	21.87	0.00	0.00
P_3, Shrink wrap	25.84	27.64	30.05	31.58	37.72	25.84	28.07	29.88	35.29	37.99	40.08	13.05	17.42	17.42	19.96	23.2	11.51	15.89	15.89	18.42	21.66	24.00
P_4, Butter paper	27.22	34.92	37.33	38.95	27.22	32.42	35.72	40.20	0.00	0.00	0.00	14.98	17.41	23.78	24.24	0.0	13.45	15.88	22.24	0.00	0.00	0.00
P_5, Muslin cloth (Control)	30.07	37.78	40.19	40.79	30.07	35.57	38.97	40.66	0.00	0.00	0.00	15.59	19.96	22.08	23.78	0.0	14.36	18.73	22.73	0.00	0.00	0.00
CD (*P*=0.05)								SE(d)						CD (*P*=0.05)					SE(d)			
P × S			5.62					2.84						2.43					1.23			

Table 2 Effect of packaging material and storage conditions on catalase activity and guaiacol peroxidase of marigold loose flower

Packaging material (P)	Catalase activity (micro mol/mg protein/min)											Guaiacol peroxidase (millimol/g FW/min)										
	Storage duration at room temperature (27±2°C)					Storage duration at low temperature (6±2°C)						Storage duration at room temperature (27±2°C)					Storage duration at low temperature (6±2°C)					
	0 day	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day	17^{th} day	0 day	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day	17^{th} day
P_1, HDPE	0.61	0.65	1.57	2.14	0.00	0.60	0.64	1.57	2.14	0.00	0.00	20.47	21.33	22.00	22.21	0.00	20.41	21.28	21.97	22.18	0.00	0.00
P_2, LDPE	1.70	1.97	2.37	247	0.00	1.70	1.96	1.37	2.47	0.00	0.00	15.05	15.90	18.01	21.38	0.00	14.98	15.85	17.97	21.80	0.00	0.00
P_3, Shrink wrap	0.37	1.64	2.26	2.67	2.73	0.54	1.21	1.62	1.85	2.52	2.87	18.62	19.48	20.15	20.74	22.94	18.56	19.43	20.12	20.71	21.22	21.89
P_4, Butter paper	0.83	1.90	2.74	2.93	0.00	0.85	1.61	3.09	0.00	0.00	0.00	19.81	20.67	21.34	22.94	0.00	19.75	20.62	21.31	0.00	0.00	0.00
P_5, Muslin cloth (Control)	0.81	1.62	2.84	3.08	0.00	0.59	2.02	3.09	0.00	0.00	0.00	20.53	21.39	22.06	23.08	0.00	20.47	21.34	22.03	0.00	0.00	0.00
CD (*P*=0.05)								SE(d)						CD (*P*=0.05)					SE(d)			
P × S			0.88					0.45						2.00					0.89			

HDPE bags (P_1). However, maximum catalase activity (1.62, 2.84 and 3.08 units) was observed under control (P_5). On 4th day shrink-wrap package flowers had catalase activity of 2.37 units.

Under low-temperature conditions the minimum catalase activity (0.64) on 4th day was recorded in flowers packed in HDPE bags (P_1) and maximum (2.02) in control (P_5). On 8th day, the minimum catalase activity (1.57) was observed in HDPE bags (P_1), while maximum (3.09) was recorded in both butter paper bags and muslin cloth bags. During 12th day, the minimum catalase activity (1.85) was observed in shrink-wrap while maximum (2.47) was observed in LDPE bags. After 15-days shrink-wrap package flowers showed catalase activity of 2.52 and 2.87 micromol/mg protein/min.

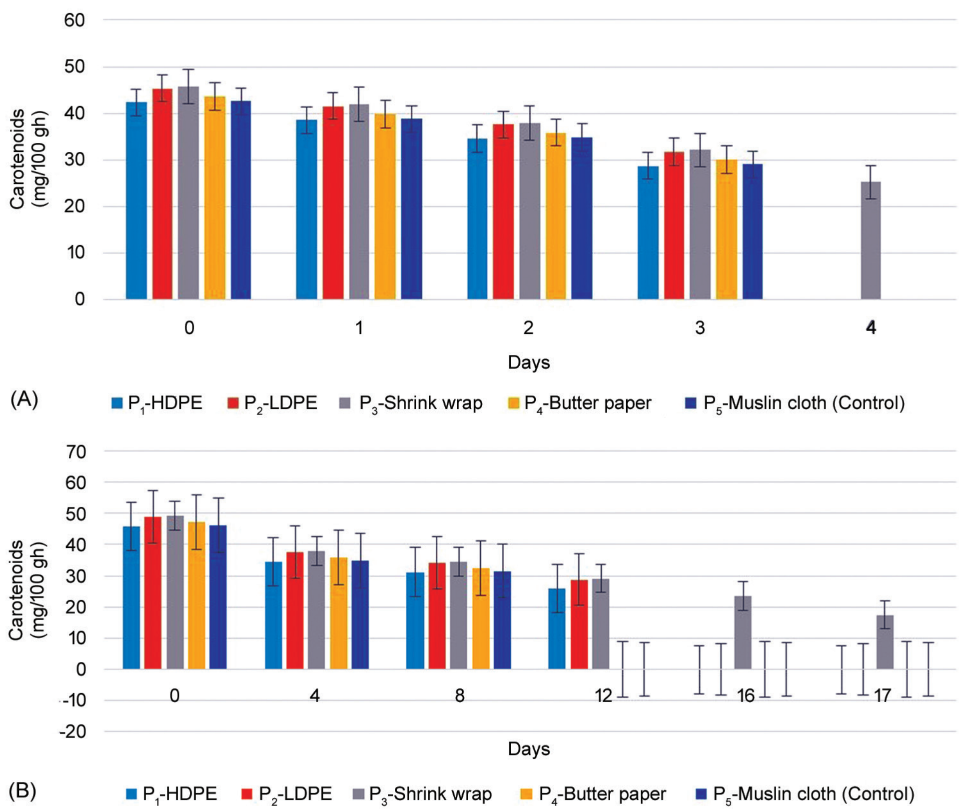

Fig. 3 Effect of packaging materials on carotenoid content (mg/100 g) of loose marigold flowers: (A) under room temperature; (B) under low-temperature storage conditions.

Guaiacol peroxidase (millimol/g FW/min): Data (Table 2) revealed that on first and second day, the minimum peroxidase activity (15.90 and 18.01) at ambient temperature conditions was recorded in flowers packed in LDPE bags (P_2) and maximum (21.39 and 22.06) was observed in control (P_5). On third day, minimum peroxidase activity (20.74) was observed in shrink-wrap while maximum (23.08) was observed in control (P_5). On 4th day, the flowers packed in shrink-wrap showed peroxidase activity of 22.94 millimol/g FW/min at ambient temperature conditions.

Under low-temperature conditions on 4th day and 8th day, minimum peroxidase activity (15.85 and 17.97) was recorded in flowers packed in LDPE bags (P_2), while maximum (21.34 and 22.03) was observed under control (P_5). On 12th day, minimum peroxidase activity (20.71) was observed in shrink-wrapped flowers (P_3) while maximum (21.80) was observed in flowers packed in LDPE bags (P_2). On 16th and 17th day, the flowers were left in shrink-wrap packaging where peroxidase activity was observed to be 21.22 and 21.89 millimol/g FW/min, respectively.

The ROS is produced from hydrogen peroxide, thus the hydrogen peroxide level regulating enzymes showed differential expression during senescence. Catalase (CAT) and peroxidase (POD) activities result in reduced production of H_2O_2 and play a major role in plant antioxidative system (Bartoli *et al.* 1995). Increased activity of peroxidase and catalase during wilting of florets has also been reported in jasmine by Jawaharlal *et al.* (2012).

Total carotenoids content (mg/100 g): The carotenoid contents recorded under room temperature conditions was observed to be (42.34, 45.34, 45.71, 43.61 and 42.61 mg/100 g) during initial days (Fig. 3). Maximum carotenoid contents observed on 1st, 2nd, 3rd and 4th day in P_3 (shrink-wrap) i.e. (41.92, 37.97, 32.15 and 25.29 mg/100 g respectively) whereas, minimum was observed in control (38.82, 34.87 and 29.05 mg/100 g respectively).

Under low-temperature conditions during initial day carotenoid contents was observed to be 45.84, 48.84, 49.21, 47.11 and 46.11 mg/100 g. Throughout storage period maximum carotenoid content was observed in flowers packed in shrink-wrap, while minimum content was observed in control on 4th and 8th day. The flowers packed in shrink-wrap exhibited maximum carotenoids content compared to control under both ambient and low-temperature conditions. Similarly, Tokas *et al.* (2018) reported that pigment content like carotene, monohydroxy, dihydroxy and xanthophyll decreased with increasing period of storage from 1st day to 13th day of storage. The decreased colour intensity was exhibited due to reduced carotenoid content. Similarly, in our study also the hue and chroma both reduced during storage under ambient and low-temperature conditions. Our findings are in agreement with the findings of Devi *et al.* (2017) and Verma and Jhanji (2022) in marigold.

From the present investigations, it is concluded that among the packaging materials, shrink-wrap proved to be the better packaging material followed by HDPE under both ambient as well as low-temperature conditions. Between storage conditions, low-temperature showed better results as compared to ambient temperature.

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