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Effect of polymeric films on physiological, biochemical and enzymatic changes in eggplant (*Solanum melongena*) under ambient conditions

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ABSTRACT

Brinjal (*Solanum melongena* L.) fruits were harvested at physiological maturity stage and packed in polymeric films, viz heat shrinkable film (15µ) and cling film (15µ). The film packed and unpacked (control) fruit were stored under ambient conditions. Both films proved quiet effective in improving the post harvest life and maintaining the quality of fruits for 6 days. Shrink and cling film created modified atmosphere around the produce and reduced physiological loss in weight (0.24 and 3.67%, respectively), shrinkage and maintained firmness (12.92 and 10.92 lb, respectively) and colour (L-23.32 and 24.59, respectively) of the fruit until 6th day of storage. Ascorbic acid (12.08 and 11.25 mg/100g, respectively) and anthocyanin content (2.50 and 1.77 mg/100g, respectively) of the fruit was better maintained in packed fruits as compared to control. Total phenols remained higher in packed fruits (52 and 48 ppm, respectively). PPO activity displayed slighter and sluggish increase as well as decrease in the packing treatments that was prompt in case of unpacked fruits and reached to the maximum level (60.63 units/100 mg) on 6th day of the storage. Thus, packaging technology helps in minimizing the postharvest losses and maintaining the quality and nutritional value of brinjal during storage under ambient conditions.

Key words: Biochemical changes, Brinjal, Enzymatic changes, Polymeric films, Shelf-life

Brinjal (*Solanum melongena* L.) is available throughout the year in the Indian markets, but, by the time it reaches the retail market, the fruits become stale and shriveled. The consumers in the market always check the outer appearance of this economically as well as nutritionally important vegetable crop. Generally, immature fruits look more fresh and attractive at harvest and are usually preferred by the consumers. Therefore, immature fruits with better appearance and internal quality are usually harvested. The loss of water from fruit surface after harvest leads to shrinkage within few days and makes unmarketable. Peel softening and shrinkage occurs due to excessive water loss caused by evapo-transpiration within 2-3 days of harvest under ambient conditions. This inferior appearance becomes a major postharvest problem, especially in summer months which affects the consumer's acceptability and marketability.

Nutritionally, brinjal is rich in chlorogenic acid (5-*O*-caffeoyl-quinic acid; CGA) that highlights its anti-oxidant, anti-inflammatory, cardio protective, anti-carcinogenic, anti-obesity, and anti-diabetic properties. Better management of storage conditions including temperature, relative humidity and gaseous composition greatly conserves the nutritional as well as consumer quality of the fruits (Kandoliya *et al*. 2015).

The concept of consumer packaging needs promotion in Indian markets, where the required quantity of vegetable can be displayed in packets in the retail out-lets for attracting consumers. It builds up an important link between growers, processor and consumers. Packing of vegetables in polymeric films creates modified atmospheric conditions (RH) around the produce with lower degree control of gases. Films which are used in a technique known as modified-atmosphere packaging (MAP) to establish modified conditions within packages, are highly permeable to O_2 and CO_2 (Sandhya 2010). This modified atmosphere can slow down the physiological processes of commodity resulting in reduced rate of respiration, transpiration and other metabolic processes of fresh produce (Kader 1997). This lowered rate of physiological processes leads to negligible loss in weight as well as retains better biochemical properties and maintains the sensory quality of the fruits. Thus, the aim of this study was to investigate the effects of different packaging films on post-harvest performance of brinjal during retail marketing under ordinary conditions.

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Table 1 Physiological and biochemical properties of brinjal at harvest

Observation	Harvest value	Observation	Harvest value
Firmness (lb force)	13.75	Phenol (ppm)	20.09
Dry matter (%)	8.02	PPO (units per 100 mg)	14.93
Peel lightness (L)	23.07	Anthocyanin (mg per 100g)	6.35
Peel chroma (C)	11.88	Pulp lightness (L)	23.07
Peel hue angle (H)	330.26	Pulp chroma (C)	19.75
Ascorbic acid (mg per 100g)	14.84	Pulp hue angle (H)	86.81

MATERIALS AND METHODS

Brinjal hybrid, viz PBH-3 (small oblong fruits), released for commercial cultivation under North Indian conditions was used to study the post-harvest behaviour of fruits, when wrapped with polymeric films and stored under retail market conditions. Uniform fruits were harvested from plants grown under standard cultural practices at the vegetable research farm, Punjab Agricultural University, Ludhiana, India. Fresh, immature fruits without visible defects were hand-picked, placed in plastic containers, and brought to the postharvest laboratory. These were sorted according to uniformity of size and colour of particular cultivar. The harvest values for various quality attributes were estimated before packing as described in Table 1.

Commercially available packaging films such as heat shrinkable (15 μ) and cling (15 μ) films were used for packaging of brinjal fruits in paper moulded trays (22 cm × 13 cm). Brinjal fruits were arranged in trays and then tightly sealed with different packaging films. Cling film wraps are made on locally available cling wrapping machine. However, the shrink film wrapped packs were shrunk by passing through a shrink wrapping machine at 165°C for 10 seconds. The fruits were stored under room temperature conditions, where temperature and relative humidity ranged from 15-22°C and 60-70% respectively, during the period of the experimentation.

The physico-chemical parameters were recorded immediately after harvest and at three days interval thereafter during stipulated period of storage. The physiological loss in weight (PLW) at each interval of storage was calculated by subtracting final weight from the initial weight of the fruits and expressed in per cent. Hunter colour difference meter was used to measure the colour readings as 'L' (lightness), 'a' (redness) and 'b' (blueness) scores at different storage intervals. Chroma value (C) and hue angles (H) were calculated as per the procedure described by Mclellan *et al.* (1995). The firmness of fruits was measured with the help of penetrometer using 8 mm probe (Model International Fruit Ripening) was expressed as lb force. Weighed samples were dried in oven at 70°C for 24 hr and percent dry matter was calculated from the initial and final weights. Ascorbic acid, anthocyanin content and total phenols of fruits were determined as per standard procedure and expressed in mg (%) and ppm (AOAC 2006), respectively. PPO activity of the brinjal fruits under various treatments and storage intervals was calculated as per the procedure explained by Torun *et al*. (2015). PPO enzyme activity was defined in units of enzyme activity per milligram of protein and described as percent enzyme activity in 100 milligram protein.

The experiment consisted of three packing treatment and three storage intervals with three replications for each treatment. The experiment was laid out in completely randomized design and statistical analysis was done in CRD factorial design using CPCS-1 software package. First and second factors used for the study were packing treatment and storage interval, respectively. The data was recorded and compiled for each observation. Results were compared at 5 percent level of least square differences (LSD) and interpreted.

RESULTS AND DISCUSSION

Physiological loss in weight (%): Physiological loss in weight (PLW) was significantly affected by the packaging and storage period as well as the interactions. In general, the physiological loss in weight increased with the advancement of the storage period from 3rd to 9th day (Fig 1A). The weight loss statistics of different packing treatments were quite variable during different storage intervals. The packing of brinjal fruit with heat shrinkable film reduced the weight loss to the maximum extent (0.24%), followed by cling film packing (3.67%) after nine days. However, the highest reduction (17.86%) in weight was observed in unpacked fruits at the end of storage. The postharvest weight loss in vegetable is usually due to loss of water through transpiration. Water loss is a critical factor in shortening the storage life and increasing deterioration of many fruit during storage, which reduce both market value and consumer acceptability (De Castro *et al*. 2006). The reduction in weight loss in film-packed fruits is attributed to restricted respiratory process of fruits inside the packaging films as reported by Mahajan *et al*. (2016) in bell pepper.

Firmness (lb force): The loss of firmness (lb) increased with the advancement in storage of brinjal (Fig 1B). However, the packing treatments conserved the firmness, significantly. The interaction of packing treatments and storage period did not affect the firmness (lb), significantly. At the end of storage, the fruits wrapped with heat shrinkable film maintained the maximum firmness (12.92 lb), closely followed by packed fruits in cling film (10.92lb), whereas unwrapped fruits experienced the minimum puncture load (10.83 lb). The loss of turgor pressure and degradation of cell wall contributes to the decrease in brittleness and firmness (Jha and Matsuoka 2002). The lower rate of softening in packed fruits might be due to the effect of the films in lowering the rate of respiration, delaying the ripening process and reduction in moisture loss. The preservation

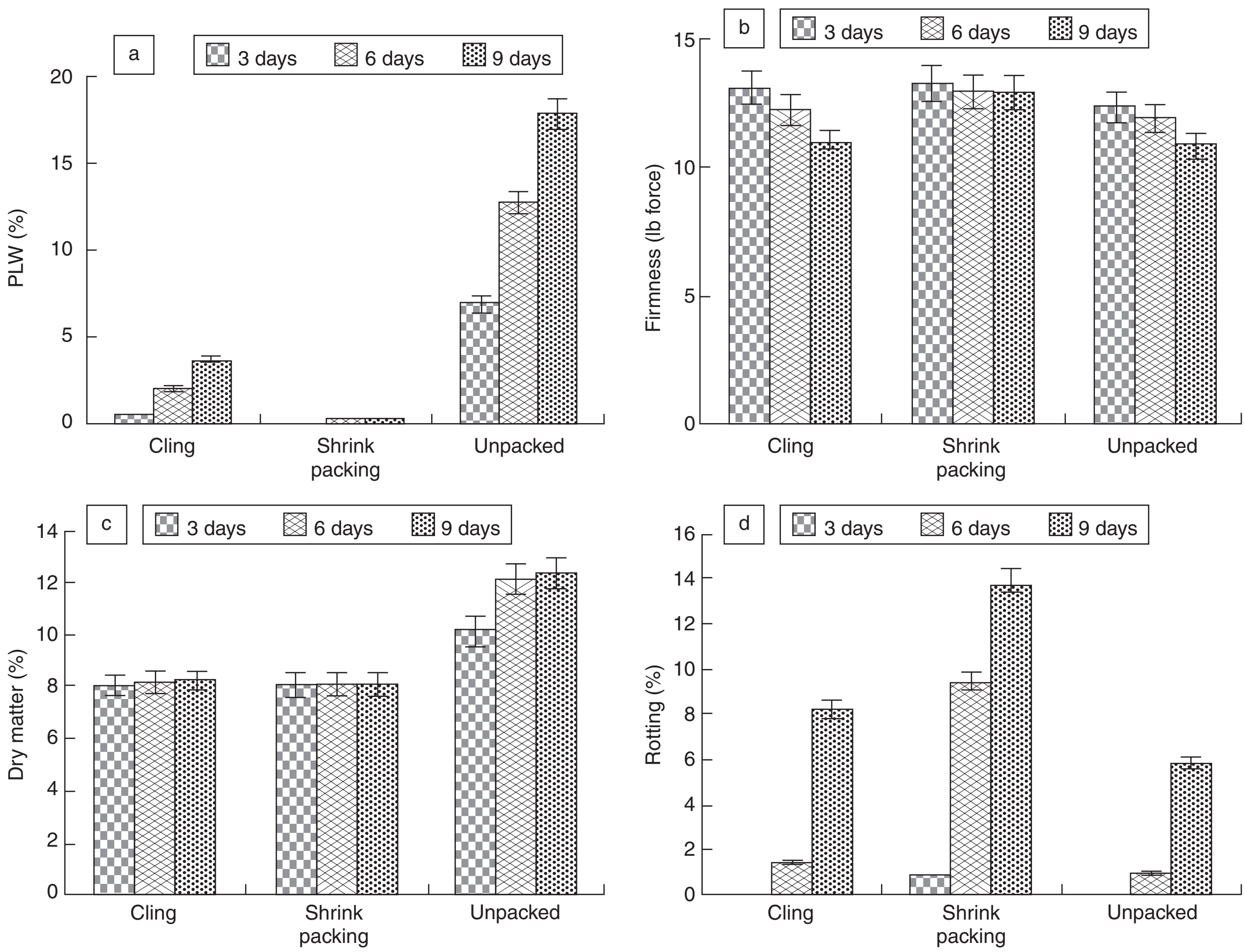

Fig 1 Influence of packaging with polymeric films on (a) PLW (%), (b) firmness (lb force), (c) dry matter (%) and (d) rotting (%) in brinjal.

of high humidity within the packing films checked the evapo-transpiration losses around the fruit surface. Thus, the films preserved the internal moisture level of the fruits and almost retained the firmness and dry matter of the fruits. The maintenance of higher firmness with heat shrinkable packaging film has been reported in many other fruits and vegetables (Sandhya 2010).

Shrinkage and rotting (%): Smooth and glossy appearance of the fruits is the main requirement for better sensory quality in eggplant. The impact of packing treatment and storage period was distinct. Both shrink and cling film wrappings conserved the outer freshness of the fruits for 9 days with no shrinkage. However, shrinkage of unpacked fruits started on 3rd day under ambient conditions, which worsen the outer appearance with the advancement of storage. Weight loss due to uncontrolled evapo-transpiration of the fruits is the main reason for shrinkage of the unpacked fruits. Whereas, the control on evapo-transpiration losses in packs resulted in the conservation of water content and maintained the firm appearance of the fruits. Hidden fungal infection may occur during post-harvest storage, especially, when the RH (> 80%) and temperature (>30°C) under ambient conditions are higher. In present investigation also, rotting (%) was recorded under high temperature and high RH conditions in September**.** Packaging with cling and shrink films enhanced the rotting of fruits under such conditions (Fig1D). But these losses were under control until 6th day, when packed fruits were kept at lower temperature (25 to 27°C) under ambient conditions. Shriveling and decay are major obstacles contributing to market losses. Film wrapping can eliminate shriveling, but decay remains the major problem for longer storage (> one week) of eggplant in rainy and humid weather. Similar reports regarding storage temperature and rotting have been given by Jha and Matsuoka (2002), who also found maximum rate of reduction of surface stiffness and volume on 4th and 5th day at >25°C as compared to lower storage temperatures and makes it unfit for cooking.

Peel and pulp colour: The packing treatment significantly affected the peel lightness (L) of eggplant, but non-significant variation was observed with the advancement of storage**.** Both the packing films maintained the lightness of the fruits, but the unpacked fruits became darker, when compared to the fruits at harvest. The storage of packed fruits non-significantly affected the peel lightness. The packed fruits in shrink (23.32) and cling (24.59) films at the end of storage remained closer to the original colour of fruits (23.07) (Fig 2A). Although, the packing and storage as well as their combined effect did not significantly change the chroma value (c), but a continuous decrease was observed in chroma of brinjal during storage. Collectively, packing and storage better retained the chroma value of shrink (6.65) as well as cling packed fruits (6.54). However, the chroma of unpacked fruits reduced from 11.88 at harvest to 4.72 at the end of storage (Fig 2C). In general, storage reduced the hue angle of brinjal fruits, but packing affected it non-significantly. The fruits packed in shrink and cling film displayed a negligible change in hue angle during the storage and maintained it as at harvest (330.26). However, the hue angle decreased with the storage of fruits in packing films and increased in the unpacked fruits. The interaction effects of packing and storage non-significantly influenced the hue angle of colour in eggplant; however, at the end of storage, shrink packs (330.38) were almost near to the original value (Fig 2E). As per the procedure for calculation described by Mclellan *et al*. (1995), the hue angle (h) for colour of fruits in brinjal came in the fourth quadrant and had purple violet hue. The hue angle boundaries for purple violet colour are 280 to 351 (Chaudhary 2015) and most of entries for brinjal during storage fall in this boundary. For example, discolouration observed mainly in the upper peel after two days was related to a decrease in C, whereas the evolution of yellow-brown colouration was associated to increases of H and L. Similar results for decrease in C and

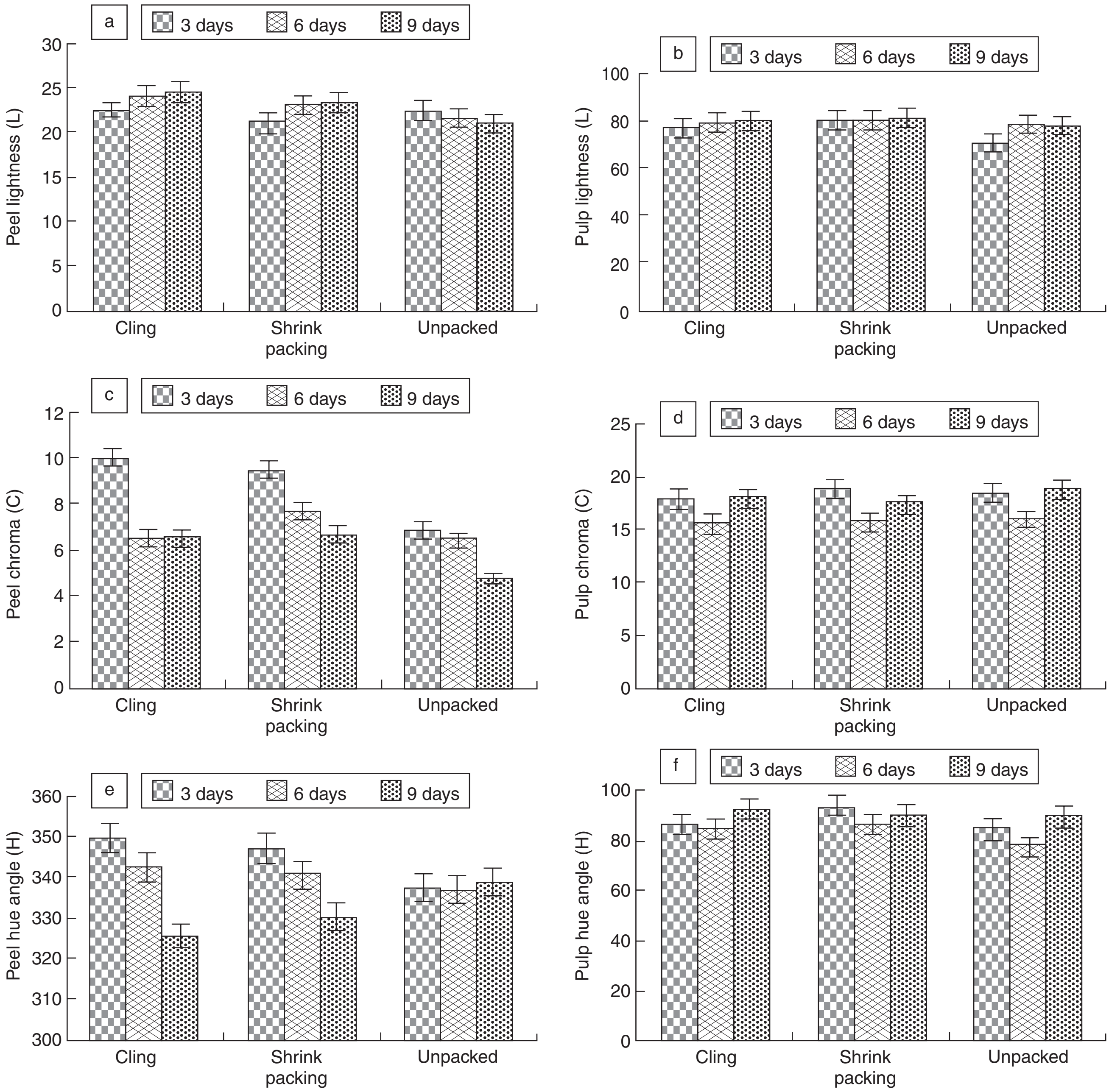

Fig 2 Influence of packaging with polymeric films on (a and b) lightness, (c and d) chroma and (e and f) hue angle of peel and pulp colour respectively, in brinjal.

increase in L and H of the upper peel of unpacked fruits stored at 10˚C were reported by Concellon *et al*. (2007). The yellow brown discolouration of the peel was the main reason for this change.

Pulp colour of the brinjal fruits also indicates its freshness. Both packing and storage influenced it significantly, but interaction effect remained insignificant for this trait. Packing with shrink (80.20) and cling (78.77) films preserved lightness (L) of pulp colour, when compared to the unpacked fruits. Generally, the storage of fruits lightened the pulp colour. However, at the end of storage, the fruits packed in shrink (80.77) and cling (80.15) films maintained the lightness. The pulp of unpacked fruits comparatively remained darker in colour (Fig 2B). Chroma (C) of the fruit pulp also first decreased from 19.75 (at harvest) to 15.78 and then increased (18.12) during storage. Packing did not change the chroma of pulp, significantly (Fig 2D). But storage of packed fruits influenced hue angle (H) of brinjal pulp, significantly. Hue angle first decreased until 6th day and increased at the end of storage. When compared with value at harvest (86.81), packing elevated the hue angle of fruit pulp, while it was found on lower side in unpacked fruits (84.24). Packing and storage had insignificant effect on hue angle. Hue angle of all the packing treatments was on higher side after storage (Fig 2F). Zaro *et al*. (2004) also reported increase in lightness of the inner zone of packed eggplants with the advancement of storage at 10˚C and decrease in hue angle of pericarp zone of packed fruits after 14 days of storage.

Ascorbic acid (mg/100g FW): The packing films and storage period in combination also had pronounced effect on the maintenance of ascorbic acid content in fruits as compared to unpacked control. Statistically, the highest retention of ascorbic acid at the end of storage was observed, when the fruits were wrapped in shrink film (12.08 mg/100g) followed cling film (11.25 mg/100g) (Fig 3A). Ascorbic acid is sensitive to degradation under adverse handling and storage conditions. The extended storage at higher temperatures, low RH, physical damage and chilling injury may enhance the losses. The modified atmosphere around packed fruits in the form of lower O_2 concentration and higher CO_2 levels may have reduced the PPO and POD activity that is responsible for loss of ascorbic acid during storage as reported earlier (Kader 1997). On the other hand, the unchecked enzymatic activity in unpacked fruits is responsible for the faster degradation of ascorbic acid.

Anthocyanin (mg/100g FW): The storage of fruits, irrespective of packaging treatments, led to the gradual degradation of this pigment from 6.36 at harvest to1.89 mg/100g at the end of storage period. The maximum of pigment in fruit peel was retained by the use of heat shrinkable film (2.50 mg/100g) followed by the cling film (1.77mg/100g). However, the unpacked fruits had the lowest amount (1.40 mg/100g) of anthocyanin at the end of storage period (Fig 3B). The reduction in respiration rates in packed fruit decelerated the biodegradation of the pigment and conserved it for longer duration in fruits as reported earlier by Kader (1997).

Total phenols (ppm): Total phenols of packed as well as unpacked fruits displayed a steady increase during storage. However, rate of increase remained higher in the packed fruits. Overall, the fruits packed in shrink film accumulated the highest level of phenols during the storage period, which was followed by the cling film packed fruits and unpacked fruits (Fig 3C). The interaction of packing treatment and storage period also significantly elevated the phenolic compounds in the fruits packed in shrink film (52 ppm) followed by cling film (44.83 ppm) at the end of storage, which was, while the lowest level was experienced in the unpacked fruits (36.32 ppm). Brinjal fruits are excellent source of antioxidants in the form of phenolic compounds. A lot of work on these compounds has already been done, but the effect of polymeric films packing on total phenolic is not in the scene. The antioxidant capacity evaluated at different storage intervals has brought a controversy for the fate of phenols after harvest. Some researchers reported the reduction, while others found an accumulation of antioxidants in the fruit during storage (Zaro *et al*. 2014). Brinjal has a big diversity of its shape, size and colour. The inherent potential of cultivars, stage of their harvest, storage conditions affecting the level of physiological activities during storage may demonstrate differential response of phenolic after harvest. Reduced respiration rates due to change in gaseous composition may have reduced PPO activities and favoured the higher accumulation of phenols in film packed fruits (Kader 1997).

Polyphenol oxidase (PPO) activity (units /100 mg): PPO activity was significantly influenced by packing and storage of brinjal fruits. Packaging of fruits, in general, with cling film (21.54 units/100 mg) as well as heat shrinkable (22.85 units/100 mg) film significantly reduced PPO activity as compared to control (32.97 units/100 mg). The PPO activity initially increased (37.70 units/100 mg) as compared to freshly harvested fruits (14.93units/100 mg), which later on decreased with the advancement of storage period. The interaction effects of packing and storage were also significant, where the highest PPO activity was observed in unpacked fruits on 6th day of storage (60.63 units/100 mg) and the lowest was again noticed in unpacked fruits (16.44 units/100mg) on 9th day (Fig 3D). Although, PPO activity initially increased in all the packing treatments, but this increase and decrease was prompt in case of unpacked fruits, while packed fruits displayed slighter and sluggish increase and decline. This might be due to the reason that oxidation processes of PPO depend upon the molecular oxygen and the modified levels of O_2 in packing films could prevent or reduce this activity of PPO to minimum as reported earlier by Kader (1997). However, the normal oxidation process due to high O_2 levels in unpacked fruits was responsible for high PPO activity. Polyphenol oxydase are the major enzyme that act on monophenols, triphenols, ascorbic acid, and *o*- and *p*-diphenols to make oxidation products and form high molecular weight polymers and macromolecular complexes from amino acids and proteins

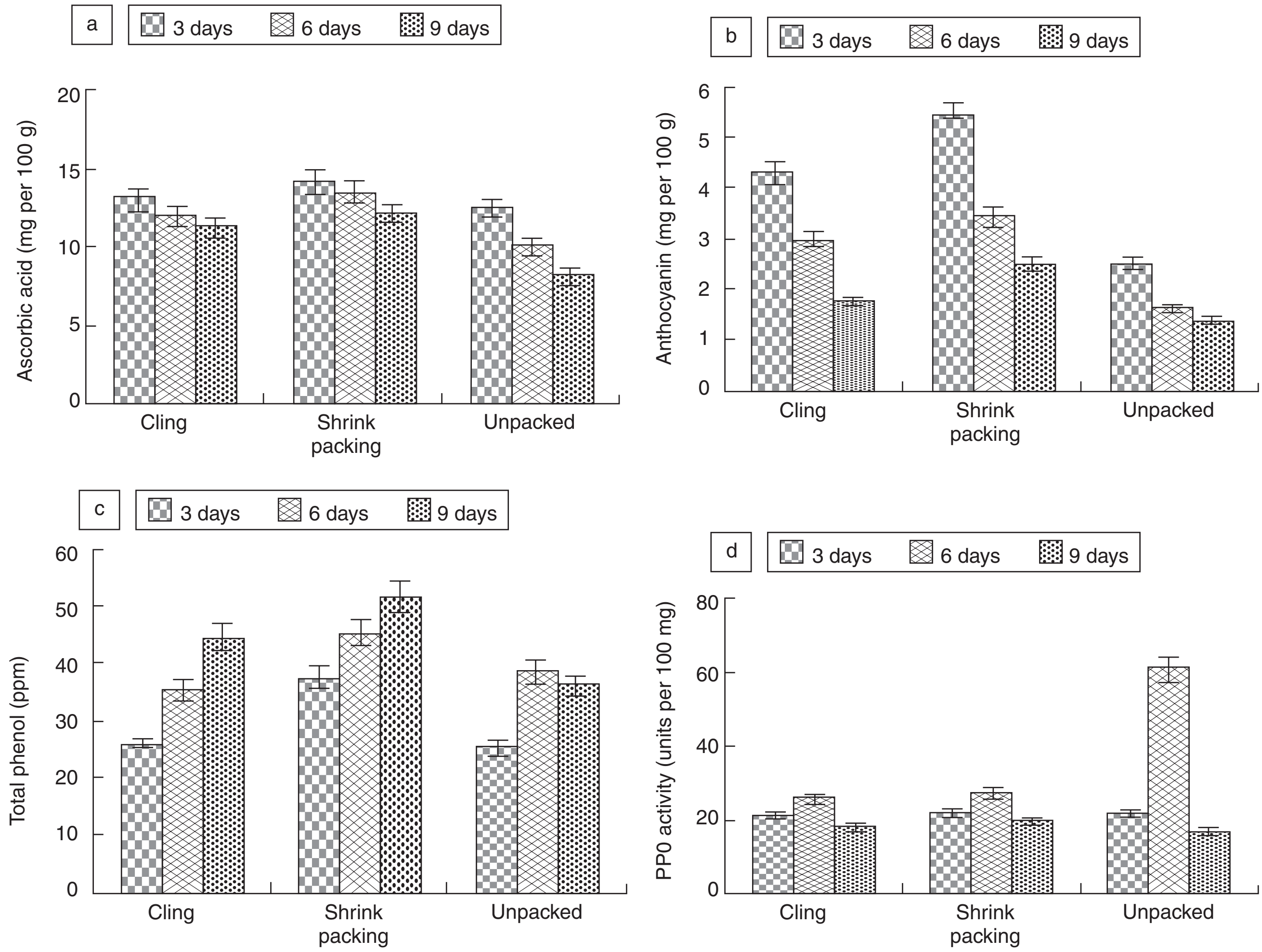

Fig 3 Influence of packaging with polymeric films on (a) Ascorbic acid, (b) Anthocyanin, (c) Total phenols and (d) PPO activity (%) in brinjal.

that are responsible for browning of the pulp in brinjal (Vamos 1981). Lower or nil activity of polyphenol oxidase enzymes in the modified environment of packs resulted in reduced degradation of phenolics and preservation of the pulp colour for longer duration.

Packaging of brinjal fruits in paper moulded trays followed by wrapping with shrink and cling film assures the improvement in the shelf-life, maintenance of the external appearance and retention of internal quality. Thus, it can enhance the consumer appeal under ordinary market conditions (25-28°C) for 6 days as compared to 2 days only in case of unpacked control. This technology can be helpful in minimizing the post harvest losses of brinjal fruits during retail marketing, providing the fresh produce with better nutritional quality to the consumer, and ultimately helping the farmers in getting remunerative prices in the market.

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