



## Assessment of packaging materials for quality attributes of tomato (*Solanum lycopersicum*) cultivars during storage

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### ABSTRACT

The effects of packaging materials [Corrugated fibre boxes (CFB), non-perforated polypropylene pouches (NPPP), perforated polypropylene pouches (PPP), plastic crates (PC), jute bags (JB)] were assessed on quality attributes in open pollinated (OP) and hybrid tomato (*Solanum lycopersicum* L.) cultivars during ambient storage (24–32°C and 70–85% RH). Tomato OP variety, Kashi Hemant had shown maximum PLW (65.2%) in PC while coded IIVR hybrid 1 exhibited minimum PLW (1.3%) in NPPP after 20 days of storage at ambient storage temperature. The maximum increase in 'a' value was also obtained in PC followed by JB, CFB, PPP and NPPP. Maximum (14.7–25.0 mg/100g) increase in ascorbic acid was obtained in hybrid Kashi Abhiman during 25 days of storage in NPPP whereas, OP variety Kashi Amrit had shown minimum increase (10–18.5 mg/100g) in ascorbic acid in PC after 15 days of storage.

**Key words:** Hybrid tomato, Open pollinated tomato, Packaging materials, Quality attributes, Tomato cultivars

Tomato (*Solanum lycopersicum* L.) is a rich source of lycopene along with fairly large amounts of  $\beta$ -carotene, vitamin C, phenolics, smaller amounts of vitamin E, flavonoids and tracer amounts of copper, manganese, and zinc (Kaur 2004). Tomato is most preferred vegetables in culinary purposes as well as it ranks first among processed vegetables in world. In India, tomato is produced on an area of 0.879 million hectare with production of 18.2 million tonnes (Indian Horticulture Database 2013). Proper harvesting of tomatoes determines the nutrient contents as well as storage durability. The ripening of tomatoes in field is very fast from breaker, turning and ripe stage. Breaker stage in tomato reflects when there is a definite break in colour from green to tarnish yellow, pink or red on not more than 10% of the surface (Sargent and Moretti 2005).

The high perishable nature of tomatoes require careful attention in the harvesting and subsequently post harvest processing operations in order to reduce the losses and meet the market demand and to fetch high market process during the lean season. The post harvest losses are due to moisture loss, rough handling, packaging, bruises, diseases and transportation. Round and thin skinned cultivars are

highly perishable as compared to pear or cylindrical and thick skinned ones. The firmness of pericarp tissue is a key component of long storability (Thorne and Alvarez 1982). Improper harvesting time (maturity), ripening conditions and lack of suitable storage facilities cause a glut during the peak harvesting period and a large portion of produce is sold at a very cheaper rate (Moneruzzaman *et al.* 2009).

The thickness of edible film had shown decisive effect towards controlling the ethylene concentration of the packaged atmosphere and for preventing the condensation of water vapour on tomato fruits and films (Garcia-Garcia *et al.* 2013). Low density polyethylene (LDPE) of different thickness had significant effect in controlling the physiological weight loss in tomatoes during storage (Yadava *et al.* 2009).

The packaging materials help in creating the modified microenvironment around the fruits and vegetables which helps in extending the shelf life with controlled physiological changes. In view of greater usage of different packaging materials in tomatoes, the present studies had been carried out to assess the suitability of the packaging materials for increasing the shelf life of selected cultivars in OP and hybrid tomatoes.

### MATERIALS AND METHODS

Tomatoes of OP cultivars of Kashi Amrit, Kashi Hemant, and Kashi Sharad and hybrid cultivars of coded institute varieties such as IIVR hybrid 1, IIVR hybrid 2 2

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and Kashi Abhiman at breaker stage were harvested from vegetable research farm of Indian Institute of Vegetable Research, Varanasi (UP), India. The tomatoes immediately after harvest were washed with water to remove the stalk and adhering dust particles followed by surface moisture was dried under fan at room temperature (24-25°C). Around 2-2.5 kg tomatoes each was packaged in CF B (14.3 cm × 16 cm × 17.7 cm, puncture resistance-1100 psi, thickness-0.4 inch/mm), (3.57μ thickness of polypropylene pouches, 25 cm × 25 cm, CO<sub>2</sub> gas permeability-92 cm<sup>2</sup>/sec, O<sub>2</sub> permeability-28 cm<sup>2</sup>/sec, water absorption-<0.02%), 4 perforations of 0.1 mm thickness in 3.57μ thickness of PPP (25 cm × 25 cm), PC diameter 25-27 cm) and JB (42 cm × 32 cm). Tomatoes packaged in PPP and NPPP were sealed with hand sealing machine. After packaging, tomatoes were stored at ambient storage conditions (24-32°C) and 70-85% RH). The physico-chemical analysis in tomatoes was recorded at 5 days of interval till the edible stage. The cumulative physiological loss in weight (PLW) of tomato fruits was calculated as per the suggested methods of Yadava *et al.* (2009). The total soluble solids (TSS) content was measured with hand refractometer (0-32° Brix at 20°C) by putting a drop of filtered juice on prism. The colour measurement in different genotypes of OP and hybrid tomato varieties was measured with colour flex meter and the values were expressed as \*a (redness) ranging from +60 (red) to -60 (green) of the International colour system. The titratable acidity, ascorbic acid and lycopene content in tomato cultivars were carried out as per the methods described by Ranganna (1997). The sensory quality of tomatoes was judged for flavour, body and texture, colour and appearance and overall acceptability by a panel of six judges on 9-point Hedonic scale (Lawless and Haymann 1998). The data obtained in triplicate were subjected to analysis of variance (Snedecor and Cochran 1967).

## RESULTS AND DISCUSSION

### Sensory score

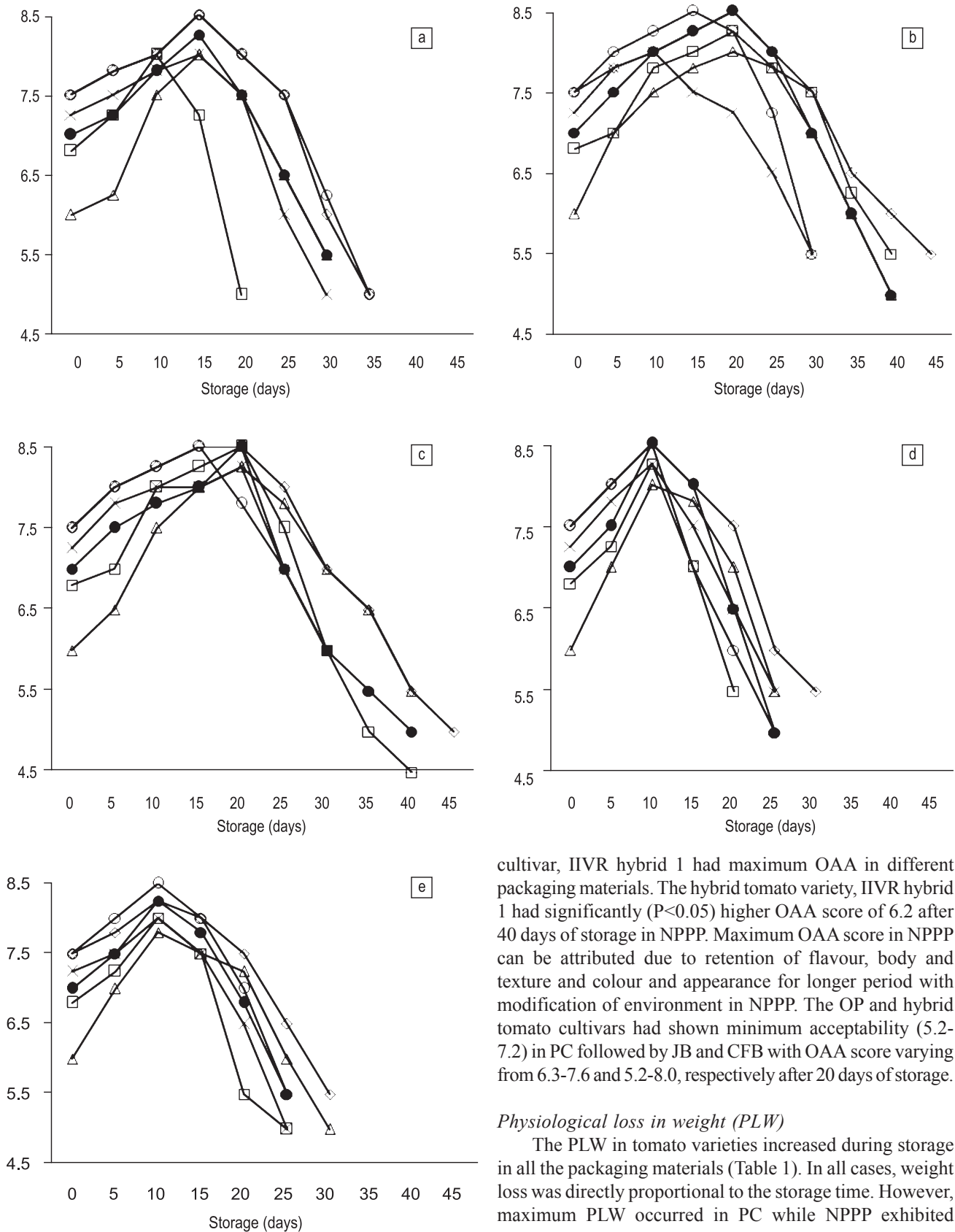
The sensory score of OP and hybrid tomato varieties increased initially and afterwards, there has been decrease in the flavour score during storage in all packaging materials. The sudden increase in flavour score was maximum (8-8.5) in PC after 10 days of storage and the minimum (7.25-8.5) increase was reflected in NPPP after 20 days of storage. However, the flavour development was comparatively of higher magnitude in hybrid tomato as compared to OP varieties during storage. The OP variety, Kashi Amrit and hybrid variety, IIVR hybrid 1 and Kashi Abhiman experienced maximum flavour score of 8.5 after 10 days of storage in PC (Fig 1). The higher flavor score of Kashi Amrit, IIVR hybrid 1 and Kashi Abhiman in PC after 10 days of storage can be attributed due to more red colour development during ripening which increased the sugar to acid ratio during ripening. Furthermore, Beckles (2012) also suggested that flavor is the complex interaction of taste and aroma. Sugars, acids, phenols and minerals are the

main constituents of tomato taste. The hybrid cultivar IIVR hybrid 1 had significant (P<0.05) effect on flavor score in all the packaging materials during storage. Sammi and Masud (2007) also reported that flavour score was increased during storage after red colour development from advance green-pink-red stage.

The increased red colour development in tomatoes is reflected with higher colour and appearance score. Different packaging materials had significant (P<0.05) effect on red colour development. However, IIVR hybrid 1 had shown maximum significant (P<0.05) effect on color development in different packaging during storage. Both OP and hybrid tomato cultivars exhibited the red colour development in different packaging materials. Maximum colour and appearance sensory score (8.5) was reflected in jute bags for, Kashi Amrit, Kashi Hemant, and IIVR hybrid 1 tomatoes after 10 days of storage which decreased afterwards due to start of senescence stage (Fig 2). Similarly good red colour development was attained with colour and appearance score of 8.5 in OP and hybrid tomatoes of Kashi Amrit, Kashi Hemant, Kashi Sharad and IIVR hybrid 1 after 20 days of storage in NPPP and PPP (Fig 2). The differences in red colour development of OP and hybrid tomatoes might be due to the fact that ripening and respiration rates varied in different packaging materials. However, higher colour and appearance score of OP and hybrid tomatoes of Kashi Amrit, Kashi Hemant, Kashi Sharad and IIVR hybrid 1 in NPPP and PPP might be reflected due to retention of red colour for longer period upto 20 days of storage. Gross (1991) suggested that colour change might be described by the hydroxylation of carotenoids and synthesis of xanthophylls.

The body and texture plays an important role in acceptability of the tomato fruits. It is an important indicator for the shelf life evaluation. It is evident from that body and texture sensory score increased with the storage period from 5 to 10 days in OP and hybrid tomato cultivars in JB and PC and the increase in the score was obtained for 15-20 days in PPP and NPPP in Kashi Sharad and IIVR hybrid 1 tomato cultivars and both cultivars had significant (P<0.05) effect of body and texture score in NPPP during storage as compared to other packaging materials. Chiesa *et al.* (1998) reported that fruit morphological and physiological characteristics of epicarp firmness, amount of locule tissue and maturity stage govern the texture in tomatoes. Furthermore, the maintenance of texture in tomatoes during packaging in PPP and NPPP for longer period can be related due to decreased water loss as the movement of water molecules slows down and reduced destruction of cell membrane structure.

Both OP and hybrid tomato cultivars had significant (P<0.05) effect on overall acceptability score in different packaging materials during storage. Both OP and hybrid tomato exhibited maximum OAA score (7.8-8.4) after 15 days of storage in NPPP and PPP (Fig 3). Judges preferred most the OP tomato variety Kashi Sharad in PC, JB and CFB and Kashi Amrit in NPPP and PPP whereas hybrid tomato



cultivar, IIVR hybrid 1 had maximum OAA in different packaging materials. The hybrid tomato variety, IIVR hybrid 1 had significantly ( $P < 0.05$ ) higher OAA score of 6.2 after 40 days of storage in NPPP. Maximum OAA score in NPPP can be attributed due to retention of flavour, body and texture and colour and appearance for longer period with modification of environment in NPPP. The OP and hybrid tomato cultivars had shown minimum acceptability (5.2-7.2) in PC followed by JB and CFB with OAA score varying from 6.3-7.6 and 5.2-8.0, respectively after 20 days of storage.

*Physiological loss in weight (PLW)*

The PLW in tomato varieties increased during storage in all the packaging materials (Table 1). In all cases, weight loss was directly proportional to the storage time. However, maximum PLW occurred in PC while NPPP exhibited

Fig 1 Sensory flavor score of tomato cultivars in different packaging materials (a) Corrugated fiber box (b) Non-perforated polypropylene pouch (c) Perforated polypropylene pouch (d) Plastic crate and (e) Jute bag during storage [Kashi amrit (●); Kashi hemant (□); Kashi sharad (△); IIVR hybrid 1 (◇); IIVR hybrid 2 (×); Kashi abhiman (○)] Values are the mean of three replication and average of 6 taste panelists

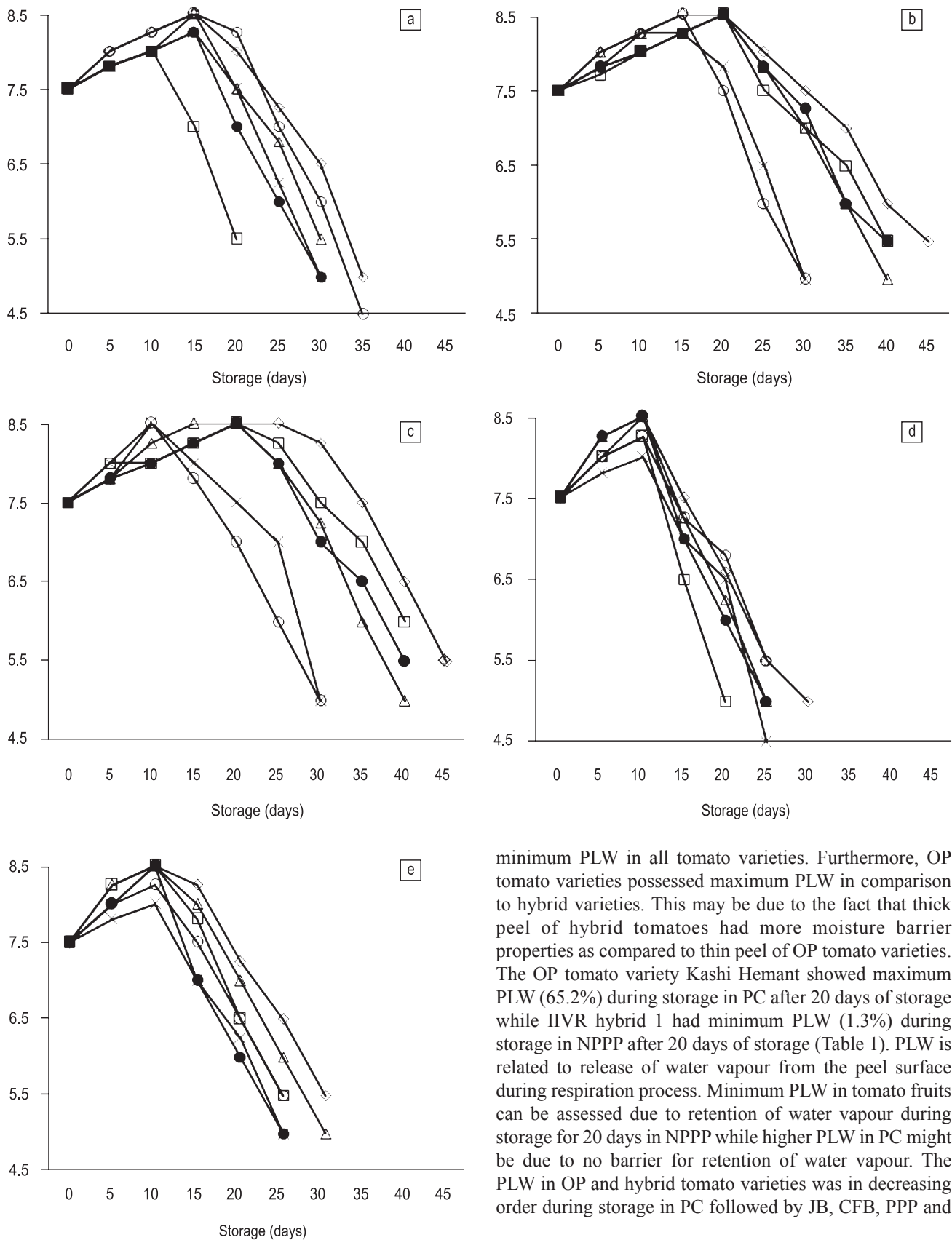
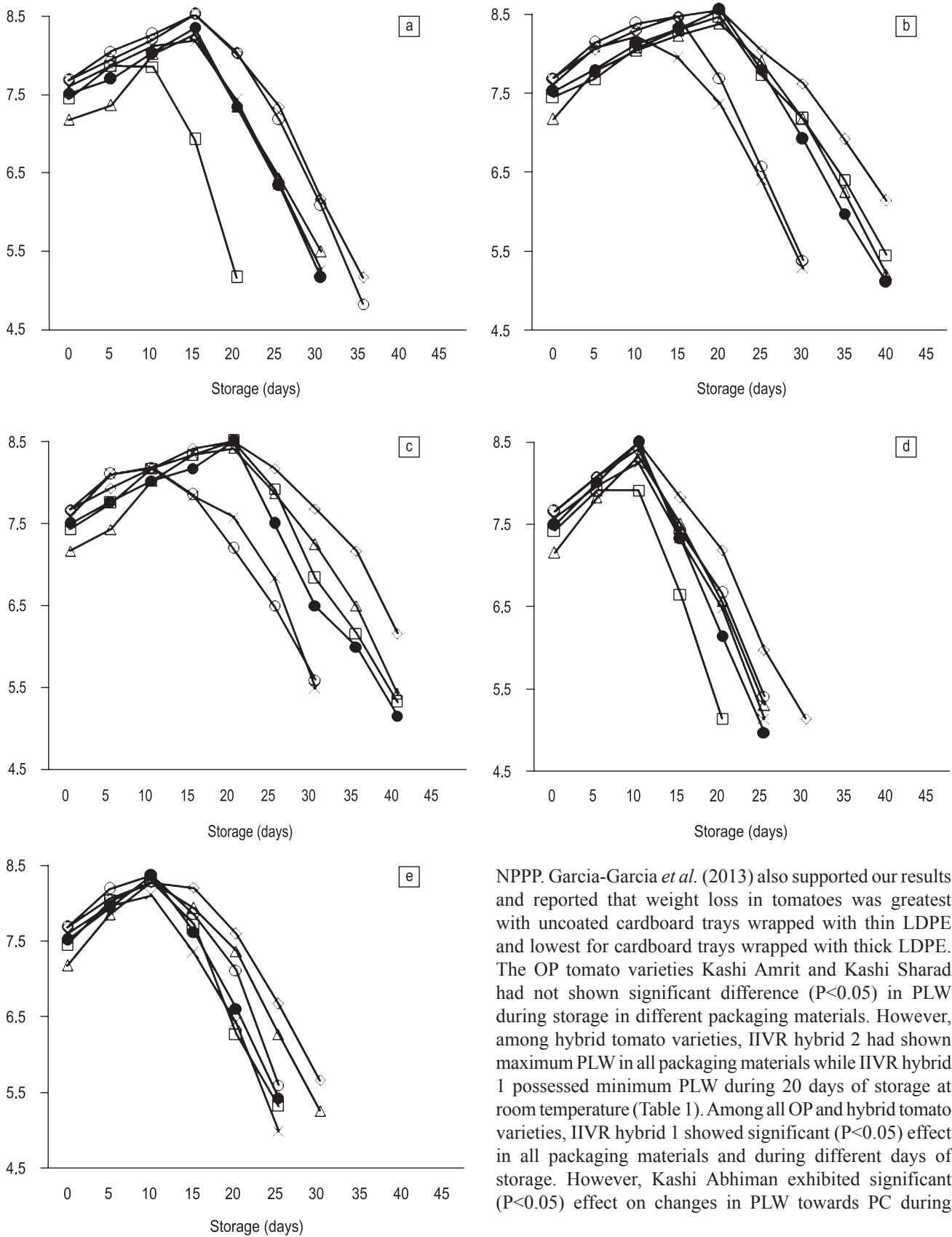


Fig 2 Sensory color and appearance score of tomato cultivars in different packaging materials (a) Corrugated fiber box (b) Non-perforated polypropylene pouch (c) Perforated polypropylene pouch (d) Plastic crate and (e) Jute bag during storage [*Kashi amrit* (●); *Kashi hemant* (□); *Kashi sharad* (△); *IIVR hybrid 1* (◇); *IIVR hybrid 2* (×); *Kashi abhiman* (○)] Values are the mean of three replication and average of 6 taste panelists

minimum PLW in all tomato varieties. Furthermore, OP tomato varieties possessed maximum PLW in comparison to hybrid varieties. This may be due to the fact that thick peel of hybrid tomatoes had more moisture barrier properties as compared to thin peel of OP tomato varieties. The OP tomato variety *Kashi Hemant* showed maximum PLW (65.2%) during storage in PC after 20 days of storage while *IIVR hybrid 1* had minimum PLW (1.3%) during storage in NPPP after 20 days of storage (Table 1). PLW is related to release of water vapour from the peel surface during respiration process. Minimum PLW in tomato fruits can be assessed due to retention of water vapour during storage for 20 days in NPPP while higher PLW in PC might be due to no barrier for retention of water vapour. The PLW in OP and hybrid tomato varieties was in decreasing order during storage in PC followed by JB, CFB, PPP and



NPPP. Garcia-Garcia *et al.* (2013) also supported our results and reported that weight loss in tomatoes was greatest with uncoated cardboard trays wrapped with thin LDPE and lowest for cardboard trays wrapped with thick LDPE. The OP tomato varieties Kashi Amrit and Kashi Sharad had not shown significant difference ( $P < 0.05$ ) in PLW during storage in different packaging materials. However, among hybrid tomato varieties, IIVR hybrid 2 had shown maximum PLW in all packaging materials while IIVR hybrid 1 possessed minimum PLW during 20 days of storage at room temperature (Table 1). Among all OP and hybrid tomato varieties, IIVR hybrid 1 showed significant ( $P < 0.05$ ) effect in all packaging materials and during different days of storage. However, Kashi Abhiman exhibited significant ( $P < 0.05$ ) effect on changes in PLW towards PC during

Fig 3 Sensory overall acceptability score of tomato cultivars in different packaging materials (a) Corrugated fiber box (b) Non-perforated polypropylene pouch (c) Perforated polypropylene pouch (d) Plastic crate and (e) Jute bag during storage [Kashi Amrit (●); Kashi Hemant (□); Kashi Sharad (△); IIVR Hybrid 1 (◇); IIVR Hybrid 2 (×); Kashi Abhiman (○)] Values are the mean of three replication and average of 6 taste panelists

Table 1 Changes in PLW (%) and red colour (a value) of tomato cultivars in different packaging materials during storage\*

Variety	PLW (%)										Colour value (a value)									
	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45
Kashi Amrit	0	5.7	14.1	18.2	30.1	50.2	56.8	S	S	S	-42*	-20*	2*	18*	34	41*	45*	S	S	S
Kashi Hemant	0	6.5	18.8	35.3	52.3	S	S	S	S	S	-35	-18	4*	20*	37*	42*	S	S	S	S
Kashi Sharad	0	10.0	16.7	24.7	30.3	50.8	55.7	S	S	S	-44*	-22*	-6	10	33	38	S	S	S	S
IIVR hybrid 1	0	3.4*	8.3*	16.8*	19.5*	20.2*	27.7*	32.4	S	S	-46*	-24*	-8	8	31	36	40	S	S	S
IIVR hybrid 2	0	5.2	20.4	26.7	27.2	31.4	38.4	S	S	S	-40*	-17	-7	15	33	40	44	S	S	S
Kashi Abhiman	0	3.4*	11.4*	24.7	26.3	30.5	36.1	37.6	S	S	-40*	-22*	-6	9	31	38	42	44	S	S
GM±SEM		5.7±	15.0±	24.4±	31.0±	36.6±	43.0±	35.0±			-41.2±	-20.5±	-3.5±	13.3±	33.2±	39.2±	42.7±			
CD(P<0.05)		1.0	1.9	2.7	4.6	6.0	5.7	2.6			1.6	1.1	2.1	2.1	0.91	1.0	1.1			
		1.8	3.3	4.8	8.1	9.9	9.5	3.6			2.8	1.9	3.7	3.7	1.6	1.6	1.7			
		0.8	1.6	2.8	3.2	4.9	5.7	6.1			-42*	-26*	-8	4	16*	18	36*	40	44	S
Kashi Amrit	0	0.8	1.6	2.8	3.2	4.9	5.7	6.1	9.1	S	-35	-24*	-6	8*	20*	22	38*	42*	46*	S
Kashi Hemant	0	1.3	2.5	3.8	5.6	7.4	9.8	11.2	13.4	S	-44*	-28*	-14*	-4	10	18	28	27	38	S
Kashi Sharad	0	0.7	1.5	2.5	3.0	3.2	5.6	7.2	8.7	S	-46*	-30*	-16*	-6*	8	20	26	24	36	41
IIVR hybrid 1	0	0.3*	0.72*	1.2*	1.3*	1.6*	1.7*	1.9*	2.0*	2.1	-40*	-22	-13*	4	6	24*	35	S	S	S
IIVR hybrid 2	0	0.35*	0.92	1.4	1.7	1.9	2.0	S	S	S	-40*	-20	-12*	-4	12	26*	28	S	S	S
Kashi Abhiman	0	0.36	0.82*	1.2*	1.6	1.7*	1.7*	S	S	S	-41.2±	-25±	-11.5±	0.3±	12.0±	21.3±	31.8±	33.2±	41.0±	
GM±SEM		0.64±	1.3±	2.1±	2.7±	3.5±	4.4±	6.6±	8.3±		1.6	1.5	1.5	2.3	2.13	1.3	2.1	4.5	2.4	
CD(P<0.05)		0.16	0.28	0.44	0.66	0.95	1.3	1.9	2.4		2.8	2.7	2.7	4.1	3.8	2.4	3.7	6.9	3.6	
		0.29	0.5	0.78	1.2	1.7	2.4	2.9	3.6		-42*	-24*	-4	10	24*	22	40	44	48	S
		1.2	2.7	3.3	4.9	5.9	7.8	7.9	9.2	S	-35	-22*	-2	12*	28*	26	44*	48*	50*	S
Kashi Amrit	0	1.2	2.7	3.3	4.9	5.9	7.8	7.9	9.2	S	-44*	-26*	-10*	4	18	22	36	40	46	S
Kashi Hemant	0	1.4	5.2	6.1	7.0	9.1	10.5	11.6	14.9	S	-46*	-28*	-13*	4	18	26	36	40	46	S
Kashi Sharad	0	0.1*	2.6	3.1	4.9	5.7	7.0	7.9	9.0	S	-40*	-20	-11*	10	18	30*	38	S	S	S
IIVR hybrid 1	0	0.31	0.74*	1.2*	1.4*	1.7*	1.8*	2.2*	2.2*	2.4	-40*	-18	-9*	10	15	32*	36	S	S	S
IIVR hybrid 2	0	0.42	1.1	1.5	1.9*	2.0*	2.1*	S	S	S	-41.2±	-23±	-8.2±	8.3±	20.2±	26.3±	38.3±	43±	47.5±	
Kashi Abhiman	0	0.34	0.89*	1.2*	1.6*	1.7*	1.8*	S	S	S	1.6	1.5	1.7	1.4	2.0	1.7	1.3	1.9	1.0	
GM±SEM		0.63±	2.2±	2.7±	3.6±	4.4±	5.2±	7.4±	8.9±		2.8	2.7	3.1	2.5	3.5	3.0	2.3	2.9	1.5	
CD(P<0.05)		0.21	0.70	0.78	0.95	1.25	1.53	1.95	2.6		-42*	-18*	6	22*	40	48	S	S	S	S
		0.38	1.2	1.4	1.7	2.2	2.7	3.0	4.0		-35	-6	10*	25*	45*	S	S	S	S	S
		12.7	21.0	39.4	58.5	72.5	S	S	S	S	-44*	-20*	4	14	38	52	S	S	S	S
Kashi Amrit	0	12.7	21.0	39.4	58.5	72.5	S	S	S	S										
Kashi Hemant	0	21.8	42.7	56.8	65.2	S	S	S	S	S										
Kashi Sharad	0	16.5	19.5	37.5	46.0	61.5	S	S	S	S										

Contd.

Table 1 (Concluded)

Variety	PLW (%)										Colour value (a value)									
	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45
IIVR hybrid 1	0	9.5*	18.0	22.6*	26.6*	30.7*	36.8	S	S	S	-46*	-26*	4	12	32	40	50	S	S	S
IIVR hybrid 2	0	20.6	34.8	46.2	59.6	61.2	S	S	S	S	-40*	-4	6	20	38	50	S	S	S	S
Kashi Abhiman	0	11.7*	16.7*	23.1*	31.3*	34.3*	S	S	S	S	-40*	-20*	4	13	36	52	S	S	S	S
GM±SEM		15.5±	25.5±	37.6±	47.9±	52.0±					-41.2±	-15.7±	5.7±	17.7±	38.2±	48.4±				
CD(P<0.05)		2.0	4.4	5.4	6.5	8.3					1.6	3.6	0.95	2.2	1.8	2.2				
		3.6	7.8	9.6	11.6	13.7					2.8	6.3	1.7	3.9	3.1	3.7				
Kashi Amrit	0	9.6	18.0	38.4	48.5	60.4	S	S	S	S	-42*	-20*	4*	20*	38	44	S	S	S	S
Kashi Hemant	0	20.5	41.5	55.7	64.2	S	S	S	S	S	-35	-6	6*	22*	40*	46*	S	S	S	S
Kashi Sharad	0	8.4	16.0	36.5	46.7	60.4	S	S	S	S	-44*	-20*	-2	12	36	41	52	S	S	S
IIVR hybrid 1	0	8.7	11.7*	18.9*	22.8*	28.7*	35.5*	S	S	S	-46*	-20*	-4*	16	34	39	48	S	S	S
IIVR hybrid 2	0	10.2	21.8	26.8	31.5	38.4	S	S	S	S	-40*	-20*	-6*	17	36	43	S	S	S	S
Kashi Abhiman	0	11.2	17.7	25.8	28.9	32.7	S	S	S	S	-40*	-22*	-5*	11	35	41	S	S	S	S
GM±SEM		11.4±	21.1±	33.7±	40.4±	44.1±					-41.2±	-18.0±	-1.2±	16.3±	36.5±	42.3±				
CD(P<0.05)		1.8	4.3	5.3	6.3	6.2					1.6	2.4	2.0	1.8	0.9	1.0				
		3.3	7.6	9.4	11.2	11.3					2.8	4.3	3.6	3.1	1.6	1.8				

\*Significant; S, spoiled

storage (Table 1). Garcia-Garcia *et al.* (2013) also supported our results.

*Colour*

The red colour development in tomato is initiated with the onset of ripening. The ‘a’ value symbolizes the red colour in tomatoes. The ‘a’ value in hybrid and OP tomato cultivars increased during storage in all packaging materials (Table 1). The maximum increase in ‘a’ value was reflected in PC followed by JB, CFB, PPP and NPPP during storage. The OP variety, Kashi Hemant exhibited maximum red colour (a value, 45) after storage for 20 days in PC while IIVR hybrid 2 had shown minimum red colour development (‘a’ value 6) in NPPP after 20 days of storage (Table 1). The OP tomato variety, Kashi Hemant had shown significant (P<0.05) effect on red colour development after harvesting at breaker stage and during storage in all packaging materials (Table 1). The increase in red colour development in OP and hybrid tomato varieties resulted in rapid attainment of ripening followed by senescence which ultimately resulted in spoilage after 25 days of storage in PC, CFB and JB.

*Total soluble solids (TSS)*

The TSS level in both OP and hybrid tomato cultivars increased with increasing the storage period in different packaging materials (Table 2). However, IIVR hybrid 2 had shown maximum increase in TSS (7.8%) after 20 days of storage in PC and OP variety, Kashi Sharad possessed minimum increase in TSS content (3.2%) after 20 days of storage in NPPP and PPP, respectively. It is evident from Table 2 that the increase in TSS level was more in hybrid tomato varieties as compared to OP varieties in different packaging materials. The TSS level was maximum in PC followed by JB, CFB, PPP and NPPP packaging materials. The increase in TSS level can be attributed due to successive stages of maturation and is correlated with hydrolytic changes which causes degradation of polysaccharides such as starch, hemicelluloses and pectin to simple sugars thus ultimately increases the TSS level (Dumvilli and Fry 2000). Among the tomato cultivars of OP and hybrid, IIVR hybrid 2 had shown significant (P<0.05) effect on increase in TSS value in all the packaging materials during storage.

*Titrateable acidity*

Among the OP tomato varieties, Kashi Sharad exhibited maximum increase (48.4%) while hybrid tomato variety, IIVR hybrid 2 had minimum increase (15.7%) in acidity after 30 days of storage in PPP (Table 2). It is reflected that the increase in acidity of OP and hybrid tomato cultivars was maximum in

Table 2 Changes in TSS (%) and titratable acidity (% citric acid) of tomato cultivars in different packaging materials during storage\*

Variety	TSS										Titratable acidity										
	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45	
	<i>CFB</i>																				
Variety	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45	
Kashi Amrit	3.2	3.4	3.6	3.8	4.0	4.4	4.8	5.0	5.2	5.4	0.372	0.421	0.47	0.519	0.568*	0.519*	0.47*	S	S	S	S
Kashi Hemant	4.0	4.6	4.8	5.0	5.2	S	S	S	S	S	0.395	0.444	0.483	0.532	0.54	S	S	S	S	S	S
Kashi Sharad	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.2	S	S	0.351	0.4	0.449	0.498	0.547	0.498	0.449	S	S	S	S
IIVR hybrid 1	4.8	5.0	5.2	5.8	6.2	6.6	8.0	8.2	S	S	0.402	0.451	0.5	0.522	0.537	0.488	0.439	0.39	S	S	S
IIVR hybrid 2	6.2*	6.8*	7.4*	7.8*	8.0*	8.4*	8.6*	S	S	S	0.452*	0.492*	0.531*	0.544*	0.55	0.501	0.452	S	S	S	S
Kashi Abhiman	5.0	5.4	5.8	6.0	6.4	7.0	7.4	8.0	S	S	0.433*	0.476*	0.525*	0.539	0.542	0.493	0.444	0.395	S	S	S
GM±SEM	4.4±	4.7±	5.0±	5.3±	5.6±	6.1±	6.6±				0.40±	0.45±	0.49±	0.53±	0.55±	0.50±	0.45±	0.39±			
	0.49	0.55	0.61	0.64	0.65	0.83	0.88				0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00			
CD(P<0.05)	0.88	0.97	1.1	1.1	1.2	1.4	1.5				0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00			
	<i>NPPP</i>																				
Kashi Amrit	3.2	3.2	3.2	3.2	3.4	3.4	3.6	3.8	4.0	S	0.372	0.403	0.434	0.465	0.496	0.527	0.496	0.465	0.434	S	
Kashi Hemant	4.0	4.0	4.0	4.0	4.2	4.2	4.4	4.8	5.0	S	0.395	0.426	0.457	0.488	0.515	0.521	0.49	0.497*	0.466*	S	
Kashi Sharad	3.0	3.0	3.0	3.0	3.2	3.4	3.6	3.6	4.0	S	0.351	0.38	0.411	0.442	0.473	0.504	0.473	0.44	0.409	S	
IIVR hybrid 1	4.8	4.8	4.8	4.8	5.0	5.2	5.4	5.6*	6.0*	6.2	0.402	0.433	0.464	0.495	0.526	0.557*	0.522*	0.491*	0.46*	0.429	
IIVR hybrid 2	6.2*	6.4*	6.6*	6.6*	6.8*	7.0*	7.2*	S	S	S	0.452*	0.483*	0.491*	0.522*	0.532*	0.539	0.508	S	S	S	
Kashi Abhiman	5.0	5.2	5.4	5.6*	5.8*	6.0*	6.2*	S	S	S	0.433*	0.464*	0.495*	0.526*	0.533*	0.544	0.513*	0.482	S	S	
GM±SEM	4.4±	4.4±	4.5±	4.5±	4.7±	4.9±	5.1±	4.4±	4.7±		0.40±	0.43±	0.46±	0.49±	0.51±	0.53±	0.50±	0.48±			
	0.49	0.53	0.56	0.57	0.57	0.60	0.60	0.46	0.48		0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01			
CD(P<0.05)	0.88	0.94	1.0	1.0	1.0	1.1	1.1	0.71	0.73		0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.02			
	<i>PPP</i>																				
Kashi Amrit	3.2	3.2	3.2	3.4	3.6	3.8	4.0	4.2	4.2	S	0.372	0.414	0.456	0.498	0.54	0.556	0.516	0.414	0.476	S	
Kashi Hemant	4.0	4.0	4.0	4.2	4.4	4.6	4.8	5.0	5.2	S	0.395	0.437	0.479	0.521	0.563*	0.574	0.534	0.437	0.487	S	
Kashi Sharad	3.0	3.0	3.0	3.2	3.2	3.4	3.6	3.8	3.8	S	0.351	0.393	0.435	0.477	0.519	0.561	0.521	0.393	0.481	S	
IIVR hybrid 1	4.8	4.8	5.0	5.2	5.4	5.6	5.8	6.0*	6.2*	6.4*	0.402	0.444	0.486	0.528	0.57*	0.588*	0.566*	0.444*	0.52*	0.48	
IIVR hybrid 2	6.2*	6.4*	6.8*	7.0*	7.2*	7.4*	7.4*	S	S	S	0.452*	0.487*	0.529*	0.542*	0.557	0.563	0.523	S	S	S	
Kashi Abhiman	6.2*	6.4*	6.8*	7.0*	7.2*	7.4*	7.4*	S	S	S	0.433*	0.475*	0.517*	0.532*	0.548	0.554	0.514	S	S	S	
GM±SEM	4.6±	4.6±	4.8±	5.0±	5.2±	5.4±	5.4±	4.7±	4.8±		0.40±	0.44±	0.48±	0.52±	0.55±	0.57±	0.53±	0.42±	0.49±		
	0.58	0.62	0.69	0.69	0.71	0.71	0.64	0.49	0.54		0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		
CD (P<0.05)	1.0	1.1	1.2	1.2	1.3	1.3	1.1	0.74	0.82		0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.02
	<i>PC</i>																				
Kashi Amrit	3.2	3.8	4.0	4.4	4.8	5.0	S	S	S	S	0.372	0.442	0.512	0.558	0.488	0.418	S	S	S	S	
Kashi Hemant	4.0	4.8	5.0	5.4	5.8	S	S	S	S	S	0.395	0.465	0.535	0.563	0.493	S	S	S	S	S	

Contd.



Table 3 Changes in ascorbic acid (mg/100g) and lycopene (mg/100g) of tomato cultivars in different packaging materials during storage\*

Variety	Ascorbic acid										Lycopene									
	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45
Variety	<i>CFB</i>																			
Kashi Amrit	10.0	12.6	15.2	17.8	20.4	17.8	15.2	S	S	S	0.30	1.2	1.6	2.3	2.5	3.5*	3.6*	S	S	S
Kashi Hemant	11.7	14.3	16.9	19.5	22.0	19.4	S	S	S	S	0.50	1.4*	3.0*	3.8*	3.9*	S	S	S	S	S
Kashi Sharad	10.6	13.2	15.8	18.4	20.9	18.4	15.8	S	S	S	0.29	1.2	1.5	2.3	2.4	3.1	3.3	S	S	S
IIVR hybrid 1	12.8	15.4	17.9	20.5	23.1	20.5	17.9	S	S	S	0.15	0.76	0.27	2.9	2.9	2.9	3.1	3.2	S	S
IIVR hybrid 2	15.3*	17.4*	20.0*	22.3*	24.9*	22.3*	19.7*	S	S	S	0.98*	1.3	1.9	2.6	3.0	3.1	3.5	S	S	S
Kashi Abhiman	14.7*	17.3*	19.8*	22.0*	24.6*	22.0*	19.41*	16.8	S	S	0.40	0.89	1.3	2.9	2.9	3.0	3.2	3.3*	S	S
GM±SEM	12.5±	15.0±	17.6±	20.1±	22.7±	20.1±	17.6±				0.44±	1.1±	1.6±	2.8±	2.9±	3.1±	3.3±	3.2±		
	0.88	0.83	0.83	0.76	0.76	0.76	0.91				0.12	0.10	0.36	0.22	0.22	0.09	0.09	0.03		
CD(P<0.05)	1.6	1.5	1.5	1.4	1.4	1.4	1.5				0.21	0.18	0.64	0.40	0.39	0.15	0.16	0.04		
Variety	<i>NPPP</i>																			
Kashi Amrit	10.0	12.4	14.7	17.0	19.3	21.7	19.3	17.0	14.2	S	0.30	0.31	0.41	0.42	0.61	0.69	0.72	0.89	1.23	S
Kashi Hemant	11.7	14.0	16.4	18.7	21.0	23.4	21.0	18.7	16.3	S	0.50	0.54	0.61	0.62	0.69	0.76	0.89	1.2*	1.5*	S
Kashi Sharad	10.6	12.9	15.2	17.6	19.9	22.2	19.9	17.6	15.2	S	0.29	0.30	0.33	0.35	0.48	0.52	0.56	0.61	0.87	S
IIVR hybrid 1	12.8	15.2	17.5	19.8	22.2	24.5	22.2	19.8*	17.5*	15.2	0.15	0.18	0.34	0.44	0.47	0.50	0.55	0.77	0.86	0.72
IIVR hybrid 2	15.34*	16.55*	18.1*	20.43*	22.44*	24.77*	22.44*	S	S	S	0.98*	0.99*	1.0*	1.1*	1.1*	1.7*	2.0*	S	S	S
Kashi Abhiman	14.7*	16.8*	19.1*	21.0*	23.1*	25.0*	22.7*	S	S	S	0.40	0.41	0.49	0.78	0.98*	1.1	1.6*	S	S	S
GM±SEM	12.5±	14.6±	16.8±	19.1±	21.3±	23.6±	21.2±	18.3±	15.8±		0.44±	0.46±	0.53±	0.62±	0.72±	0.89±	1.04±	0.88±	1.13±	
	0.88	0.75	0.69	0.65	0.61	0.57	0.57	0.62	0.71		0.12	0.12	0.10	0.11	0.11	0.19	0.24	0.13	0.16	
CD(P<0.05)	1.6	1.3	1.2	1.2	1.1	1.0	1.0	0.95	1.1		0.21	0.21	0.18	0.20	0.19	0.35	0.43	0.20	0.25	
Variety	<i>PPP</i>																			
Kashi Amrit	10.0	12.5	15.0	17.5	19.9	22.4	19.9	17.5	15.0	S	0.30	0.39	0.56	0.49	0.60	0.79	0.88	0.91	1.8*	S
Kashi Hemant	11.7	14.2	16.7	19.1	21.6	24.1	21.6	19.1*	16.0*	S	0.50	0.58	0.65	0.69	0.75	0.88	0.95	1.27*	1.6	S
Kashi Sharad	10.6	13.1	15.2	17.7	20.2	22.7	20.2	17.7	15.2	S	0.29	0.31	0.37	0.40	0.46	0.56	0.65	0.69	0.99	S
IIVR hybrid 1	12.84	15.28	17.76	20.24	22.72	23	20.52	18.04	15.56	13.08	0.15	0.19	0.35	0.47	0.49	0.52	0.56	0.79	0.88	0.74
IIVR hybrid 2	15.3*	17.8*	20.3*	21.3*	23.8*	24.4*	21.9*	S	S	S	0.98*	0.99*	1.01*	1.56*	1.12*	1.19*	1.22*	S	S	S
Kashi Abhiman	14.7*	17.1*	19.6*	22.1*	24.1*	24.9*	22.0*	S	S	S	0.40	0.41	0.48	0.53	0.55	0.59	0.64	S	S	S
GM±SEM	12.5±	15.0±	17.4±	19.7±	22.1±	23.6±	21.0±	18.1±	15.4±		0.44±	0.48±	0.57±	0.69±	0.66±	0.76±	0.82±	0.92±	1.3±	
	0.88	0.88	0.91	0.78	0.73	0.42	0.38	0.37	0.22		0.12	0.11	0.10	0.18	0.10	0.10	0.10	0.13	0.24	
CD(P<0.05)	1.57	1.57	1.61	1.38	1.30	0.74	0.67	0.57	0.34		0.21	0.20	0.18	0.32	0.18	0.19	0.18	0.19	0.37	
Variety	<i>PC</i>																			
Kashi Amrit	10.0	12.8	15.7	18.5	15.7	12.8	S	S	S	S	0.30	1.5	2.6	2.7	3.6	3.9*	S	S	S	S
Kashi Hemant	11.7	14.5	17.3	20.2	17.3	S	S	S	S	S	0.50	2.1*	3.6*	4.5*	5.5*	S	S	S	S	S
Kashi Sharad	10.6	13.4	16.2	19.0	16.2	13.4	S	S	S	S	0.29	2.0*	2.4	2.6	3.2	3.6	S	S	S	S

Contd.

Table 3 (Concluded)

Variety	Ascorbic acid										Lycopene									
	0	5	10	15	20	25	30	35	40	45	0	5	10	15	20	25	30	35	40	45
IIVR hybrid 1	12.8	15.7	18.5	21.3*	18.5*	15.7*	12.8	S	S	S	0.15	0.79	1.3	2.9	3.0	3.1	3.2	S	S	S
IIVR hybrid 2	15.3*	17.0*	19.8*	21.0*	18.2*	15.0	S	S	S	S	0.98*	1.4	2.0	3.0	3.0	3.6	S	S	S	S
Kashi Abhiman	14.7*	16.6*	18.2	20	17.2	14.4	S	S	S	S	0.40	0.92	1.3	2.9	3.0	3.2	S	S	S	S
GM±SEM	12.5±	15.0±	17.6±	20.0±	17.2±	14.2±					0.44±	1.5±	2.2±	3.1±	3.5±	3.5±				
CD(P<0.05)	0.88	0.69	0.63	0.45	0.45	0.51					0.12	0.22	0.36	0.28	0.40	0.15				
	1.57	1.23	1.11	0.79	0.79	0.84					0.21	0.40	0.64	0.51	0.71	0.25				
Kashi Amrit	10.0	12.7	15.4	18.1	15.4	12.7	S	S	S	S	0.30	1.3	2.3	3.0	3.4	3.8	S	S	S	S
Kashi Hemant	11.7	14.4	17.1	19.8	17.1	14.4	S	S	S	S	0.50	2.0*	3.6*	3.8*	4.4*	5.2*	S	S	S	S
Kashi Sharad	10.6	13.3	16.0	18.7	16.0	13.3	10.6	S	S	S	0.29	1.5	2.3	2.5	3.1	3.4	3.9	S	S	S
IIVR hybrid 1	12.8	15.5	18.2	20.9	18.2	15.5	12.8	S	S	S	0.15	0.79	1.3	2.9	2.9	3.1	3.1	S	S	S
IIVR hybrid 2	15.3*	18.0*	20.7*	23.0*	20.3*	17.2*	S	S	S	S	0.98*	1.4	2.0	3.0	3.0	3.3	S	S	S	S
Kashi Abhiman	14.7*	17.4*	19.5*	22.2*	19.5*	16.8*	S	S	S	S	0.90*	1.3	2.9	3.0	3.0	3.2	S	S	S	S
GM±SEM	12.5±	15.2±	17.8±	20.5±	17.8±	15.0±	11.7±				0.52±	1.4±	2.4±	3.0±	3.3±	3.7±				
CD(P<0.05)	0.88	0.88	0.84	0.80	0.80	0.76	1.13				0.14	0.18	0.32	0.18	0.24	0.32	0.41			
	1.57	1.56	1.49	1.42	1.42	1.35	1.59				0.25	0.32	0.57	0.32	0.42	0.56	0.58			

\*Significant; S, spoiled

in NPPP and PPP (0.56-0.65 mg/100g) after 30 days of storage (Table 3). The rate of lycopene development in OP and hybrid tomato cultivars during storage was maximum in PC followed by JB, CFB, PPP and NPPP. Ajlouni *et al.* (2001) reported that the increased level of lycopene might be due to ripening advancements in tomato fruits and conversion of chloroplasts to chromoplasts. Among the tomato varieties, Kashi Hemant had shown significant (P<0.05) effect on increased lycopene development during storage in PC, JB, and CFB. However, tomato cultivars exhibited non-significant effect on the increased lycopene development in PPP and NPPP during storage upto 30-35 days of storage (Table 3).

It was concluded that the shelf life of hybrid and OP tomato varieties are limited to 25-30 days in NPPP and PPP and 15-20 days of storage in PC, JB and CFB at room temperature. The OP variety, *Kashi hemant* exhibited maximum red color (a value, 45) in PC while *IIVR hybrid 2* had shown minimum red color development (a value, 6) in NPPP after 20 days of storage. The rate of lycopene development in OP and hybrid tomato cultivars during storage was maximum in PC followed by JB, CFB, PPP and NPPP.

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