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Effect of Different Packaging Systems on Storage Life and Quality of Tomato (*Lycopersicon esculentum* var. Rio Grande) during Different Ripening Stages

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Different packaging systems are developed in our laboratory and evaluated for their suitability to extend storage life and improve the quality of tomato (var. Rio Grande) fruits. Freshly harvested mature green tomatoes were packed in polyethylene packaging with or without treating with calcium chloride, boric acid and potassium permanganate. The fruits were then evaluated for changes in quality parameters within the different stages of ripening. The treatments improved the storage life up to 96 days as compared to that of control (24 days). The quality parameters were studied throughout the ripening and data through every stage was discussed. The results showed that within each ripening stage, the treated fruits remained better than that of control and all the ripening stages and treatments are significantly different ($p<0.05$) from each other. It can also be deduce that treated fruits showed lower weight loss (%), TSS contents and titratable acidity while ascorbic acid contents, sugar to acid ratio, flavour, texture, colour and overall acceptability was higher in treated fruits as compare to control at the red stage of ripening. Total sugars (%) were low in fruits treated with calcium chloride and boric acid with or without potassium permanganate.

Keywords: Tomato, *Lycopersicon esculentum*, potassium permanganate, calcium chloride, boric acid, quality

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The tomato was said to be the first target of plant biotechnology to understand the phenomenon related to ethylene production and its relationship to ripening. Tomato is a climacteric fruit, having respiratory peak during their ripening process. Being a climacteric and perishable vegetable, tomatoes have a very short life span, usually 2-3 weeks. An increase in the storage life and improvement of tomato fruit quality is really desirable. Potassium permanganate removed the exogenous ethylene from atmosphere, which played a central role in tomato fruit ripening (Kader, 1994) by absorbing and oxidizing it to carbon dioxide and water (Wills *et al.*, 1981; Thompson, 1994; Roth, 1999), thus increasing concentration of carbon dioxide and blocked the synthesis of endogenous ethylene (Miyazaki and Yang, 1987; Mehta *et al*., 1987), which is said to be essential for control of ripening as its synthesis is believed to be essential for many plant developmental processes including ripening (Klee *et al*., 1991). Different studies explained that calcium chloride reduced post harvest decay, controlled development of physiological disorders, improved quality and delayed aging or ripening (Grant *et al*. 1973; Stanly *et al.*, 1995). It improves the skin strength (Mignani *et al.*, 1995) making the cell wall and tissues more resistant and less accessible to the enzymes that produced by fungi and bacteria limiting infection while controlling ripening, softening, storage breakdown, rotting and decay at the same time (Conway and Sam, 1984; Poovaiah, 1986; Sams *et al.* 1993; Izumi and Watada, 1994; Hong and Lee, 1999). According to different studies, it improved the Ca^{+2} contents, lycopene contents, ascorbic acid contents, firmness index (Subbiah and Perumal, 1990; Gracia *et al*., 1996) and reduced the disease index (Scott and Wills, 1979; De-Souza *et al.*, 1999). Boric acid inhibited the ethylene production, ripening and disease incident (Wang and Morris, 1993). Tomato is a beautiful fruit to look upon and most people eat it with great relish (cooked, in salad, or out of hand). An increase in the storage life and improvement of tomato fruit quality is really desirable and the initial step required for ensuring successful marketing is to harvest the crop at the optimum stage of maturity. Full red, vine-ripened tomatoes may be ideal to meet the needs of a roadside stand, but totally wrong if the fruits are destined for long distance shipment (Wagner *et al*., 2001). In present study, the objective is to evaluate the different packaging systems containing polyethylene packaging, potassium permanganate, calcium chloride and boric acid to improve the storage life and to access the quality of tomato fruits.

MATERIALS AND METHODS

Harvesting and handling. Tomato fruits were harvested at mature green stage from tomato field located at Batal, Mansehra, NWFP, Pakistan. At this stage fruits exhibited a white to yellow “star” on the blossom end and a jelly like material was well developed in locules. These fruits were cooled in shade and placed in wooden boxes having layers of paper at bottom and all sides. After every layer of tomato fruits, a layer of paper was placed to reduce incidence of physical damage. Then these wooden boxes were transported to storage area. Firstly Fruits were washed from normal tap water. Fruits were dried in air.

Solution preparation. Different solutions used in these packaging systems are prepared accordingly. Saturated solution of $KMnO_4$ was prepared by dissolving solid $KMnO_4$ in 1 liter distilled water until any more $KMnO_4$ cannot able to dissolve at ambient temperature. Four hundred (400) ppm solution of $KMnO_4$ was prepared by dissolving 0.4 g (400 mg) in 100 ml of distilled water and making the volume up to 1000 ml or 1 liter. One percent (10000 ppm) $CaCl_2$ was prepared by dissolving 10 g $CaCl_2$ in 100 ml of distilled water and making the volume up to 1000 ml/1 liter of distilled water. Thousand (1000) ppm boric acid was prepared by dissolving 1 g boric acid in 100 ml of distilled water and making the volume up to 1000 ml or 1 liter of distilled water.

Execution of treatments

Packaging system 1 (PS1). Fruits are placed in polyethylene packs of 0.44 mm thickness and sealed leaving 3-4 inches of head space in the packs.

Packaging system 2 (PS2). In packaging system 2, fruits were dipped in $CaCl_2$ solution for 1-2 min, removed and dried. After dipping fruits in $CaCl_2$, they were dipped in boric acid solution for 30-60 sec., removed and dried. These fruits were than placed as two fruits per package and polyethylene packs were than sealed leaving 3-4 inches of head space in the packs (3-4 inches down from the top.

Packaging system 3 (PS3). Sponge cuttings were made by 1 cubic inch cuttings (1 x 1 x1 inches) by a cutting knife. These sponge cuttings were then dipped in the saturated $KMnO_4$ solutions. After that these sponge cuttings were allowed to dry to an extent that no drop of $KMnO_4$ will be dripped from them. Then, one cutting per bag was placed in the bag at one corner and sealed the side accepted to touch the fruits. Fruits were dipped in $CaCl_2$ solution for 1-2 min, removed and dried. After dipping fruits in $CaCl_2$, they were dipped in boric acid solution for 30-60 sec., removed and dried. These fruits were than placed in 2 fruits per package containing potassium permanganate dipped sponges and polyethylene packs were than sealed 3-4 inches of head space in the packs.

Storage. Four packs of each treatment were then placed in one cardboard carton made of 40 no. sheet. After treating and packaging, the fruits were kept at ambient temperature (with an average value of 28-30ºC) in the storage area as only three cartons were placed on top of each other to ensure proper air movement around the cartons.

Ripening stages. The ripening stages are determined by the appearance of tomato fruits according to Jimenez (1996) and Sergent and Moretti (2004) that green Fruit has surface is completely green; the shade of green may vary from light to dark. At breaker stage there is a definite break in colour from green to tannish-yellow, pink or red on not more than 10% of the surface. At turning, 10% to 30% of the surface is not green which in the aggregate, shows a definite change from green to tannish-yellow, pink, red, or a combination thereof. At pink stage, 30% to 60% of the surface is not green; in the aggregate, shows pink or red colour. Light red fruits showed 60% to 90% of the surface as not green which in the aggregate, shows pinkish-red or red colour. At red ripening stage showed more than 90% of the surface is not green which in the aggregate, shows red colour. The data then presented as green (1^{st} day of storage for all fruits), Advanced green to turning (0 to 8^{th} day for control and 0 – 32^{nd} day for treated fruits), pink to pink red means 8^{th} to 16^{th} day for control and 32^{nd} to 64^{th} day for treated fruits while pink red to red means 16 to 32 days for control and 64^{th} to 96^{th} day for treated fruits.

Fruits analysis. These fruits were analyzed after every 7 days for a period of 96 days. All the physico-chemical analysis was performed according to methods of AOAC (1990) and sensory evaluation was done on the basis of 9 point hedonic scores (1 for extremely poor and 9 for excellent) according to Steel and Torrie (1979).

Data analysis. The data obtained was statistically analyzed for analysis of variance in two-factor factorial Complete Randomized Design (CRD) using MSTAT-C (Michigan State Univ. microcomputer program, 1991) and significant differences were determined according to Waller-Duncan K ratio LSD rule at K=100 level of statistical significance.

RESULTS AND DISCUSSION

The results regarding physico-chemical and sensory quality parameters are presented in table 1-5. The control showed an entirely different pattern as it displayed fast ripening rate and went through all these stages in 24 days of storage. On the other hand, treated fruits exhibited very slow ripening changes, reaching red stage of ripening at 96^{th} day of storage at ambient temperature. table 1-5 divulged that all the ripening stages differed with high significance ($P < 0.05$) with respect to each other for all the quality parameters. With slow ripening, the rate of change in all physico-chemical and organoleptic attributes was also very slow. It can also be seen that all the treatments differed in the effect on quality parameters within each ripening stage. The fruits were analyzed at interval of 7 days for 96 days

Table 1: Weight loss (%) and TSS (ºBrix) of control and treated fruits during different ripening stages.

Attributes	Treatments	Green	Advance Green - Turning	Pink – Pink Red	Pink Red – Red

Weight loss (%)	Control	0.00 m	3.87 i	7.128 d	11.903 a
	PS1	0.00 m	1.675 l	4.269 h	6.8495 e
	PS2	0.00 m	2.832 j	6.584 g	9.693 b
	PS3	0.00 m	2.221 k	5.23 f	7.927 c
Total soluble solids (ºBrix)	Control	3.00 m	4.666 f	5. 00 d	5.250 a
	PS1	3.00 m	3.958 j	4.395 g	4.979 e
	PS2	3.00 m	3.699 k	4.321 h	5.083 b
	PS3	3.00 m	3.616 l	4.161 i	5.02 c

*the values followed by same alphabets are not significantly ($P < 0.05$) different from each other for each different attribute.

and at the end of storage means were calculated for all treatments within each ripening stage. The effect of treatments on quality parameters is described as below:

Weight Loss (%). It is evident from the table 1 that weight loss percentage increased significantly ($P < 0.005$) as the ripening proceeds. Control not only displayed rapid increase in weight loss (%) showing highest weight loss percentage at the end of storage period as compare to all other treatments at that stage. This is due to the uncontrolled ripening in control fruits as ripening in tomatoes is climacteric which showed a sudden increase in ethylene production and respiration rate (Anon., 2004a). This higher respiration rate also resulted in higher transpiration of water from the fruit surface which led to increase in percentage of weight loss (Sabir *et al.*, 2004).

Table 2: Titratable Acidity (%) and Ascorbic Acid (mg/100 ml) of control and treated fruits during different ripening stages.

Attributes	Treatments	Green	Advance Green - Turning	Pink – Pink Red	Pink Red – Red
Titratable Acidity (%)	Control	0.579b	0.576 b	0.597 a	0.499 e
	PS1	0.579b	0.414 h	0.424 g	0.284 j
	PS2	0.579b	0.527 d	0.426 g	0.239 k
	PS3	0.579b	0.466 f	0.570 c	0.356 i
Ascorbic Acid (mg/ 100 ml)	Control	5.94 m	6.414 l	11.01 i	26.30 e
	PS1	5.94 m	8.267 k	27.39 d	37.18 b
	PS2	5.94 m	10.533 j	25.395 f	38.915 a
	PS3	5.94 m	11.79 h	22.99 g	35.287 c

*the values followed by same alphabets are not significantly ($P < 0.05$) different from each other for each different attribute.

Packaging significantly ($P < 0.05$) reduce the weight loss from the fruits through every stage of ripening. It showed 50 % less weight loss as compare to control between advanced green to breaker stage. This pattern continues till the end of each ripening stage as when packed fruit reaches red stage of ripening, it displayed 40% lower weight loss as compare to control. These results fall in line with the result showed by Batu and Thompson (1998) that sealed pack tomatoes showed less weight loss after 60 days of storage. This lower weight loss percentage was due to the permeability of the packaging materials which generates a modified atmosphere around the fruits (Anon., 2003). This permeable nature of packaging material changes the relative humidity inside the sealed packs leading to lower moisture loss and transpiration rate. This lower transpiration rate associated with lower weight loss percentage (Ben-Yehoshua, 1985; Tariq *et al.*, 2001). The use of calcium chloride and boric acid was not proved to be best in reducing weight loss percentage as compared to packed fruits but this weight loss is significantly lower (20%) than that of control ones at red stage. However, with use of potassium permanganate with calcium chloride and boric acid, the weight loss percentage was significantly lower than that of fruits without potassium permanganate and control ones. The potassium permanganate is said to by an ethylene degrading chemical which degrades ethylene into water and carbon dioxide. Water accumulated in packs created a high humid environment retarding transpiration and water loss (Wills *et al.*, 1981; Thompson, 1994; Roth, 1999).

It is accessed that weight loss percentage in chemical treated fruits was higher than that of simply packed. Calcium chloride controlled the ripening by reducing PG expression of activity and production of pectic oligomers which induce ripening. It retard changes and reduce mitochondrial activity and ripening, however according to Luna-Guzman *et al*. (1999) ethylene production rate was higher in Ca^{++} treated fruits although metabolic activity appeared to be reduced with low respiration rate. This increased ethylene production might cause the higher weight loss as compare to all other treatments, however, when potassium permanganate sponges were placed in sealed packs along with calcium chloride treated fruits the ethylene produced degraded and so did weight loss percentage. Boric acid significantly reduced the ethylene and carbon dioxide production, thus reducing the rate of respiration and ripening (Wang and Morris, 1993). This reduced respiration led to the lower weight loss percentage.

Total Soluble Solids (ºBrix). Total soluble solids (ºBrix) of control and treated tomato fruits showed that they increased as the ripening proceeds. It can easily be accessed from the table 1 that control showed highest TSS contents through out the ripening as compare to all other treatments which means at every ripening stage, ripening of control fruits really advanced and more rapid than that of treated ones. Table 1 also revealed that up to pink red stage of ripening packed fruits showed highest TSS contents followed by both PS2 and PS3. However, during pink red to red stage of ripening simply packed fruits showed the lowest TSS (4.979) followed by fruits packed with PS3 (5.02) and fruits packed with PS2 (5.083) as compare to that of control (5.250). The significantly ($P < 0.005$) low TSS contents in treated fruits were the result of delayed ripening by the action of PS2 (Clarke *et al.*, 1997; Izumi and Watada, 1994; Kader, 1994).

Changes in TSS contents were natural phenomenon occurred during ripening and is correlated with hydrolytic changes in starch concentration during ripening in post harvest period. In tomatoes, conversion of starch to sugar is an important index of ripening (Kays, 1997). During ripening the degradation of cell wall polysaccharides (hemicellulose and pectins) occurred which led to the release of oligosaccharins. These oligosaccharins are the oligosaccharides with biological activity and potential inter-cellular signaling role (Albersheim and Darvill 1985; Ryan and Farmer 1991; Aldington and Fry 1993; Cote and Hahn 1994; Dumville and Fry 2000). Exogenous oligosaccharins (synthesised in vitro or isolated from non-plant sources) can influence fruit ripening. For example, certain in-vitro hydrolysis products of plant cell walls can induce ethylene biosynthesis (Baldwin and Biggs 1988). These oligosaccharides promoted the initiation of ripening in tomato fruit (Priem and Gross 1992). The Ca+2 ions formed the salt- bridge cross links with the COO- groups from the pectin contents of the fruits and vegetables (Grant *et al.* 1973; Stanly *et al.*, 1995) reducing solubalization of pectin (Magee *et al.*, 2002) and forming calcium pactate which stabilized the membrane system, thus reducing the production of oligosaccharides resulting lower rate of ripening and lower TSS contents.

Titratable Acidity (% in terms of citric acid). Generally titratable acidity decreased significantly ($P < 0.05$) with passage of time with faster rate in treated fruits (table 2). Control fruits exhibited highest percentage of acidity throughout the storage with each ripening stage. After control, during pink-red stage of ripening, PS3 showed the highest acidity contents. The reason is that the use of $KMnO_4$ contributes to an increase in the CO_2 concentration as ethylene is degraded into CO_2 and water by the action of $KMnO_4$ (Wills *et al.*, 1981). This CO_2 accumulated in the fruit tissue and after dissolving formed carbonic acid, causing acidiosis (Carrillo *et al*. 1995). The PS1 and PS2 proved to the best acidity decreasing factors. The low acidity contents at the end of the storage period were probably due to the packaging as described by Badshah *et al*. (1997) and Batu and Thompson (1998).

According to Bhattacharya (2004) acidity is often used as an indication of maturity, as acid decreases on ripening of fruit. It has also been reported that during the ripening of tomatoes, malic acid disappears first, followed by citric acid (which result in reduction of amount of titratable acidity), suggesting the catabolism of citrate via malate (Mattoo *et al*., 1975; Salunkhe and Desai, 1984). Salunkhe *et al.* (1974) stated that the sugar of tomato fruit juices increases during ripening, whereas the acidity declines after the first appearance of yellow colour in normal ripening. It then started to increase again but after that increase acidity started to decrease, probably due to disappearance of citric acid. Disappearance of malic and citric acid during ripening process may be the main factor responsible for the reduction in titratable acidity during the storage. The microorganisms may use citric acid as a carbon source, hence, resulting in reduction in the titratable acidity

Ascorbic Acid (mg/ 100 ml juice). Table 2 indicated the effect of packaging, calcium chloride, boric acid and potassium permanganate on the ascorbic acid contents of fruits during ripening. It is evident that the ascorbic acid contents were significantly increased with the ripening of tomatoes exhibiting the highest amount of ascorbic acid during pink-red to red stage of ripening. It can also be accessed that fruits treated with calcium chloride showed the highest ascorbic acid followed by that of simply packed fruits. Among packaging systems, PS3 showed lowest ascorbic acid contents. The reason for high ascorbic acid in fruits treated with calcium chloride is that it increased the ascorbic acid contents as evaluated by Subbiah and Perumal (1990). The high carbon dioxide atmosphere affected the ripening rate, delaying ascorbic acid production. Use of boric acid also enhanced the ascorbic acid retention in tomatoes.

Table 3: Total Sugars (%) and Sugar to Acid Ratio of control and treated fruits during different ripening stages.

Attributes	Treatments	Green	Advance Green - Turning	Pink – Pink Red	Pink Red – Red
Total Sugars (%)	Control	2.865 l	4.999 a	4.651 c	4.417 d
	PS1	2.865 l	3.928 h	3.998 f	4.9445 b
	PS2	2.865 l	3.235 l	3.409 k	4.018 e
	PS3	2.865 l	3.587 i	3.944 g	4.022 e
Sugar to Acid Ratio	Control	4.79 m	8.637 j	7.79 j	8.821 f
	PS1	4.79 m	10.239 d	10.06 e	18.539 a
	PS2	4.79 m	6.256 l	8.497 h	16.95 c
	PS3	4.79 m	8.018 i	6.938 k	12.393 d

*the values followed by same alphabets are not significantly ($P < 0.05$) different from each other for each different attribute.

Total Sugars (%). Total sugar percentage is an important factor for determining the quality of the tomato fruits. The flavour of a product depends on total sugar percentage. Table 3 showed that the during the advanced green to turning stage of ripening the control showed highest amount of sugars, however this gradually decreased as the ripening proceeds. The free sugars in commercial varieties of tomatoes are reducing sugars and quantity of sucrose is negligible (Gould, 1983). It can be seen that among fruits treated with PS2 and PS3 was lower than that of packed fruits. The main reason for this is control of ethylene by boric acid and potassium permanganate (Wang and Morris, 1993; Thompson, 1994) and ethylene was shown to have an effect on glucose and according to Lizana (1976) ethylene treatment influenced glucose and fructose increasing the total sugars of banana fruits. The packed fruits showed highest total sugars at the end of the storage (Pink-red to red stage of ripening) as with decreased rate of respiration the conversion of sugars into carbon dioxide and water is also reduced.

Sugar to Acid Ratio. It can easily be accessed from the table 3 that sugar to acid ratio increased with advances in ripening. At the last stage of ripening packed fruits showed the highest sugar to acid ratio. This was due to the highest total sugars and low acid contents of the fruits. The table 3 also revealed that PS2 showed highest sugar to acid ratio as compare to that with PS3 although their total sugar contents were the same. This was due to the high acidity of the fruits treated with potassium permanganate which might be due to the accumulation of acids in the fruit tissues (Carrillo *et al*. 1995). Sugar to acid ratio is an important factor for determining the taste of the fruits.

Table 4: Texture (scores) and Colour (scores) of control and treated fruits during different ripening stages.

``	Treatments	Green	Advance Green - Turning	Pink – Pink Red	Pink Red – Red
Texture	Control	5.00 m	6.40 l	6.85 h	7.33 g
	PS1	5.00 m	6.432 k	7.837 f	8.555 b
	PS2	5.00 m	6.677 i	7.987 d	8.67 a
	PS3	5.00 m	6.635 j	7.957 e	8.360 c
Colour	Control	3.95 l	4.25 k	7.50 f	6.265 g
	PS1	3.95 l	5.312 j	7.537 e	7.987 b
	PS2	3.95 l	5.392 h	7.72 c	8.125 a
	PS3	3.95 l	5.37 i	7.642 d	8.125 a

*the values followed by same alphabets are not significantly ($P < 0.05$) different from each other for each different attribute.

Flavour (scores). Table 4 exhibited the results regarding flavour of the control and untreated fruits. It showed that the highest flavour was determined in the fruits treated with PS2 followed by fruits in PS3. This was due to their sugar to acid ratio in determining taste (Anon., 2004b) and best aroma resulting in best flavoured fruits. However, although the packed fruits displayed highest sugar to acid ratio, their flavour scores were lowest in all treated fruits which might be due to the production of undesirable aroma as prolonged packaging some times led to the anaerobic respiration which cause the formation of ethanol and aldehydes contributing undesirable aroma (Speirs *et al*., 1998). In addition to four basic flavours that human recognized in food stuffs,m aromas have important influence on people choice of foods (Buttery *et al.*, 1971; Linforth *et al*., 1994) and as these scores are the result of decision of panel of judges, their choice of aroma has led to the lower flavour scores for packed (without chemical treatment) tomato fruits. Flavor is a combination of taste and aroma sensations. The four tastes, sweet, sour, salty, and bitter are perceived by certain regions of the tongue, while volatiles are perceived by the olfactory nerve endings of the nose (Acree, 1993). The pleasant sweet-sour taste of tomatoes is mainly due to their sugar and organic acid contents. Of the over 400 volatiles determined, 30 have proved to be the most important compounds contributing to the aroma of tomatoes. The characteristic tomato flavor, thus, is produced by the complex interaction of the volatile and non-volatile components (Petro-Turza, 1987; Buttery and Ling, 1993a).

Texture (scores). The texture played an important role in acceptability of the tomato fruits. Texture is an important attribute to evaluate the quality of tomato fruit and it is determined by the fruit morphological and physiological characteristics: epicarp firmness, amount of locule tissue and maturity stage (Chiesa *et al*., 1998b). From table 4, it is revealed that the texture scores increase with passage of ripening stages in all fruits however, in control the texture scores were remain low throughout. It is accessed that fruits packed with PS2 showed the highest texture scores throughout the ripening. The reason is the use of calcium chloride is explained with different studies that calcium chloride reduced post harvest decay, controlled development of physiological disorders, improved quality and delayed aging or ripening. Ca^{+2} ions formed the salt- bridge cross links with the COO- groups from the pectin contents of the fruits and vegetables (Grant *et al.* 1973; Stanly *et al.*, 1995) reducing solubalization of pectin (Magee *et al.*, 2002) and forming calcium pactate which stabilized the membrane system and increase the rigidity of middle portion and cell wall of fruits (Stanly *et al.*, 1995). This improves the skin strength (Mignani *et al.*, 1995) making the cell wall and tissues more resistant and less accessible to the enzymes that produced by fungi and bacteria limiting infection while controlling ripening, softening, storage breakdown, rotting and decay at the same time (Conway and Sam, 1984; Poovaiah, 1986; Sams *et al.* 1993; Izumi and Watada, 1994; Hong and Lee, 1999). It enhances the quality of fruits and vegetables by improving Ca+2 contents (Bangerth *et al.*, 1972; Gracia *et al*., 1996), lycopene contents, ascorbic acid contents, firmness index (Subbiah and Perumal, 1990) and reducing disease index (Scott and Wills, 1979; De-Souza *et al.*, 1999). Polyethylene packaging also increase the textural quality of fruits due to decreased water loss as the movement of water molecules slows down, the destruction of cell structure membrane was also reduced (Greg and Santi, 1987).

Colour (scores). Table 5 displayed the colour scores of the tomato fruits. The colour was remained getting better with advances in ripening as it actually is the basis of the classification of these ripening stages. It is clearly shown that as the ripening preceded the colour of fruits changed from green to pink and pink to red classifying ripening stages as green, advanced green, breaker, turning, pin, pink red and red. From green to turning stage, the colour of fruits changed from poor to fair by showing not more than 30% of surface as not green in colour. At this stage the chlorophyll pigment start to deteriorate and beta carotein production was initialized and at maximum (Chiesa *et al.*, 1998a). When stage advances from pink to pink-red, the colour of all fruits (control and treated) was in the range of good to very good (scoring above 7 and below 8). At this stage lycopene production has started producing red colour and masking the yellow colour of beta carotein (Salunkhe and Desai, 1987). However, when fruits advanced from pink red to red stage, the colour acceptability of control fruits delayed (between 24 to 32 days of their storage) as compared to an elevated colour range for all treated fruits (between 64 to 96 days of their storage) i-e in the range of very good to excellent especially both chemical treated fruits showed excellent colour scores. This change was due to the action of treatments on the fruits as polyethylene packaging helps the colour retention as described by Badshah *et al.* (1997). Calcium chloride increased the lycopene contents as reported by Subbiah and Perumal (1990). According to Wang and Morris, the boric acid exhibited higher ripening index as compare to the control. This ripening index is based upon the ripening stage of tomato fruits and it showed that boric acid reduced the rate of change in ripening which associated with the slower rate of change in the colour of the treated fruits.

Table 5: Flavour (scores) and Overall Acceptability (scores) of control and treated fruits during different ripening stages.

Attributes	Treatments	Green	Advance Green - Turning	Pink – Pink Red	Pink Red – Red
Flavour	Control	2.80 m	3.70 l	6.18 h	6.975 g
	PS1	2.80 m	4.637 k	7.712 f	8.425 c
	PS2	2.80 m	4.757 j	7.925 d	8.62 a
	PS3	2.80 m	4.937 i	7.80 e	8.525 b
Overall Acceptab-ility	Control	3.00 l	3.65 k	6.70 g	6.975 f
	PS1	3.00 l	4.865 j	7.65 e	8.475 b
	PS2	3.00 l	5.787 h	7.875 c	8.537 a
	PS3	3.00 l	5.192 i	7.727 d	8.475 b

*the values followed by same alphabets are not significantly ($P < 0.05$) different from each other for each different attribute.

Overall Acceptability (scores). Table 5 explains the overall acceptability of control and treated tomato fruits with respect to the consumer's point of view (panel of trained judges). It divulged that control fruits showed the lower overall acceptability as compared to that of treated ones throughout the ripening. At the red stage of ripening of the control (24 to 32 days) it showed a below good overall acceptability (6.975 scores), which was due to its rapid turning of dark red colour from red. On basis of the overall acceptability, the fruits treated with PS2 showed the excellent overall acceptability followed by both simply packed and fruits containing potassium permanganate in packs. The results led to a conclusion that the main reason behind this improvement was use of calcium chloride as described by Burns and Pressy (1987), Robson *et al*. (1989), De-Souza *et al*. (1999).

CONCLUTION

Tomatoes sealed in plastic films had an extended marketable life and it affects the gaseous atmosphere around the fruit. The use of $KMnO_4$ contributed to the production of CO_2 and water in the package atmosphere, which helped in lowering the respiration and ripening processes. Accumulation of water vapors in the package environment might also cause a decrease in the transpiration rate of water from the fruit, hence lowering water loss as described by Wills *et al*. (1981). Calcium dips retarded the metabolism as indicated by the slow ripening rate. Calcium chloride improves the firmness of tomato fruits. All the treatments delayed ripening and improve the storage life and quality significantly ($p<0.05$). Treated fruits showed lower weight loss (%), TSS contents, and acidity as compared to control while ascorbic acid contents, sugar to acid ratio, flavour, texture, colour and overall acceptability were higher in treated fruits as compare to control at the red stage of ripening. Total sugars (%) were low in fruits treated with calcium chloride and boric acid with or without potassium permanganate. All these packaging systems were effective to improve the storage life and quality of fruits.

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