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Influence of Modified Atmospheric Packaging on Shelf-Life and Quality of Naturally Grown Tomato (*Solanum lycopersicum* L.) Stored Under Different Conditions

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HIGHLIGHTS

- The influence of modified atmospheric packaging and storage conditions including, temperature, and relative humidity on shelf-life and quality of tomatoes of natural farming and chemical farming is compared.
- Zero energy cool chamber was optimized for extending the shelf-life of tomatoes
- Tukey's HSD was used for significant mean separation of quality parameters and CRD and RBD designs were used for analyzing quality attributes during storage.
- This paper investigated and presented a comparison of quality parameters of SPNF and CHEM tomatoes as well as changes during storage.

Abstract: A study was conducted to record the effect of modified atmospheric packaging (MAP), storage conditions (ambient, zero energy cool chamber and refrigerated) as well as storage period on shelf-life and quality of tomatoes produced through Subhash Palekar natural farming (SPNF) and chemical farming (CHEM) systems. Freshly harvested tomatoes (SPNF and CHEM) packed in LDPE pouches (25.40 μm and 10 pin holes/100 cm2 area) and without packaging were stored under ambient (27±2 °C and 70±2% RH), zero energy cool chamber (ZECC) (17±2 °C and 82 ±2 % RH) and low temperature conditions (10±2 ºC and 90 % RH) for shelf-life studies. The shelf-life comparison was done at every two days' interval up to 24 days based on physiological loss in weight (PLW) and spoilage percentage. SPNF and CHEM tomatoes were compared on the basis of quality attributes (firmness, acidity, TSS, sugars, total phenols, antioxidant activity etc.), mineral content and sensory characteristics. Results revealed that tomato stored in refrigerated condition had significantly ($p < 0.05$) lowest PLW and spoilage incidence and highest sensory acceptability up to 24 days and was at par with ZECC stored tomatoes. Quality evaluation indicated that tomatoes grown under SPNF system contained a higher amount of total solids, total sugars, reducing sugars, ascorbic acid, total phenols and ash. The results showed that tomatoes with MAP and stored under refrigerated storage condition retained maximum quality up to 24 days followed by tomatoes stored under ZECC (18 days) compared to 12 days at ambient conditions.

Keywords: Tomato; Storage Quality; MAP; Natural Farming; Zero Energy Cool Chamber (ZECC); PLW; Sensory Acceptability.

INTRODUCTION

Natural farming is a sustainable and ecological farming approach established by a Japanese farmer "Masanobu Fukuoka" [1]. In India, this system of farming is popularly known as "Subhash Palekar Natural Farming" (SPNF) as it was introduced by Padma Shri Subhash Palekar in 2016 [2, 3]. It is also known as zero budget natural framing (ZBNF) where zero budget means "*no credit or no expense*" and natural farming means "*chemical free farming*" [4]. The main aim of this farming system is to reduce farmer's direct cost and enhancing yield and farm health by using locally available input sources [5]. In this farming system, biological pesticides like cow dung, urine, plants and human excreta etc. have been used on the crops to eradicated insects/pests or diseases instead of using harmful chemicals [6,7]. Due to lesser input cost and easy adoptability, this farming system is specifically suitable for small and marginal farmers [8]. The wide scale application of ZBNF can be helpful in reducing the use of harmful chemicals in the soil and pollution of water as well as air [9]. In Himachal Pradesh, this farming method was implemented in 2018 with the goal to convert the chemical farming (CF) system into natural farming in the state up to 2022 under the scheme of "*Prakartik Kheti Khushal Kisan*" [10]. The scientific studies are being conducted especially on seasonal vegetables by various scientists of different institutions to validate the effects of natural farming on quality and shelf-life vis-a-vis chemical farming.

Tomato, a native crop of western South America is one of the most important vegetable crops in the world. It is an important cash crop in India, particularly for small and medium scale farmers. It is currently grown on 781 thousand Ha with a production of 19 million MT [11]. Tomato can be grown from temperate to hot and humid tropical conditions as rabi as well as kharif crop [12]. Nutritionally, tomatoes are high in nutrients such as vitamin C, carotenoids, minerals (calcium, magnesium and phosphorous), dietary fibers and low in calories [13]. The major carotenoid present in it is lycopene, which is 98 % of the total (2573 μg lycopene and 42 μg of vitamin A) which is responsible for red colour of tomato [14]. It also contains about 3.18 % carbohydrates, 1.17 % protein and 0.97 % total lipids [13]. Besides its high nutritional significance, perishable nature of this crop due to its high respiration rate and higher atmospheric temperature as well as humidity during monsoon season makes it more prone to spoilage, hence hamper its long term storage and marketing [15]. In-fact, one of the major challenges is post-harvest deterioration of tomato fruit, which is one of the major concerns to the tomato industry, and leads to a huge economic loss at every step of the marketing chain, thus require proper storage conditions. The respiration rate of perishable commodities can be slow down by altering the storage conditions surrounding the commodities [2]. Low temperature and high relative humidity play a crucial role and can effectively reduce the rate of deterioration of freshly harvested commodities [16]. The recommended safe storage temperature for tomato is 5-13 ºC but due to sensitivity towards chilling injury they are generally stored above 10 ºC [17]. ZECC is an eco-friendly, low cost method of post-harvest handling of fruits and vegetables, which works on the principle of evaporative cooling [18]. Suitable high humidity and low temperature for fresh fruits and vegetables can be maintained inside it that has significant effect on shelf-life [19].

On the other hand, air composition during storage of fresh produces greatly influence physiological, biochemical processes, impacts freshness, and storage life [20]. In modified atmosphere packaging (MAP), conducive condition such as low O_2 and high CO_2 level can be maintained inside the film, which helps in retaining freshness and quality for longer time [21]. The gases under these modified packaging such as depleted O_2 and elevated CO_2 alter the physiological processes and reduce the rate of reaction inside the fruit and thus reducing the rate of oxidation, microbial spoilage and delay ripening of fresh produce [2]. With the current demand for chemical free healthy foods and the desire to make them available for longer period, the current study was conducted with the goal of extending the postharvest shelf life of tomatoes grown under the SPNF system through modified atmospheric conditions using polyethylene film and low temperature storage.

MATERIAL AND METHODS

Experimental details

In the present investigation, fresh tomato (*Solanum lycopersicum* L. cv. *Solan Lalima)* grown under SPNF (Subhash Palekar natural farming) and CHEM (Chemical farming system) were harvested at turning point stage of maturity during the month of August, 2020 from SPNF farm, Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) and immediately brought to Post-harvest Physiology laboratory of Department of Food Science and Technology for conducting further studies. The fruits were washed properly, diseased as well as spoiled fruits were discarded, and physico-chemical analysis was done. The polymer packaging material used to create the MAP condition was obtained from Pep Cee Pack Industries, India, which was manufactured using supreme quality raw material. Packaging roll had a transparent orientation and plain pattern with 10-MPa tensile impact-resistant strength, which had been UV stabilized; 25.40-μm film had an oxygen transmission (100% oxygen) rate of 6200 $g/m^2/24$ h at 25ºC temperature and 45% relative humidity; water vapor transmission rate of 18 $g/m^2/24$ h at 38ºC temperature and 90% RH and CO_2 permeability was three fold higher than the O_2 transmission rate of the film.

To evaluate the effect of MAP during storage, the harvested tomatoes were divided into two lots, in first half tomato fruits (1 kg each) were packed in LDPE pouches (25.40 μm thickness) already perforated with 10 pin holes per 100 cm^2 area and tied up with thread. The other half was kept as such without any packaging material in 3 different storage conditions. In total, twelve numbers of treatments were coded as described in Table 1.

Table 1. Detail of treatments

Treatment	Code	Treatment details
T_1	SPNF AO	Subhash Palekar natural farming tomato- without packaging and stored at ambient conditions
T_2	CHEM AO	Chemical farming system tomato- without packaging and stored at ambient conditions
T_3	SPNF AP	Subhash Palekar natural farming tomato- packed in LDPE and stored at ambient conditions
T_4	CHEM AP	Chemical farming system tomato- packed in LDPE and stored at ambient conditions
T_5	SPNF ZO	Subhash Palekar natural farming tomato- without packaging and stored in ZECC
T_6	CHEM ZO	Chemical farming system tomato- without packaging and stored in ZECC
T_7	SPNF ZP	Subhash Palekar natural farming tomato- packed in LDPE and stored in ZECC
T_8	CHEM ZP	Chemical farming system tomato- packed in LDPE and stored in ZECC
T_9	SPNF RO	Subhash Palekar natural farming tomato- without packaging and stored at refrigerated conditions
T_{10}	CHEM RO	Chemical farming system tomato- without packaging and stored at refrigerated conditions
T_{11}	SPNF RP	Subhash Palekar natural farming tomato- packed in LDPE and stored at refrigerated conditions
T_{12}	CHEM RP	Chemical farming system tomato- packed in LDPE and stored at refrigerated conditions

All the treatments were kept for further comparative storage evaluation with three replications under ambient condition (28±2ºC and 70±2% RH), in zero energy cool chamber (18±2ºC and 83± 2%) and refrigerated temperature condition (10±2 ºC and 90 % RH) (Figure 1). The comparison was done on the basis of PLW and spoilage at interval of two days.

a) Ambient and refrigerated conditions without packaging

b) Ambient and refrigerated conditions with packaging

c) ZECC with and without packaging

Figure 1. Tomato stored under ambient, refrigerated and zero energy cool chamber

Quality evaluation of tomato fruits

Physico-chemical analysis

The effect of MAP on shelf-life was carried out on the basis of physiological loss weight in fruits and spoilage percentage. Whereas, for quality evaluation various physico-chemical and sensory attributes along with mineral profile were assessed as per standard procedures given below:

Physiological loss in weight (PLW)

The shelf-life comparison was done on the basis of physiological loss in weight (PLW) as per method of Kumar and Thakur [22] at every two days interval up to 24 days in tomato.

$$\text{PLW (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100$$

Spoilage

For the estimation of the extent of fruit spoilage, spoiled fruits (fungal rot and infections) were counted on each sampling date. The total number of fruits spoiled during the entire storage duration was calculated by adding up all the diseased fruits from successive storage intervals as described by Kumar and Thakur [22].

$$\text{Spoilage (\%)} = \frac{\text{Number of fruit spoiled}}{\text{Total number of fruits stored initially}} \times 100$$

Respiration rate

The rate of respiration was measured as CO_2 evolved per unit weight of fruit per unit time. Known weight of fruit was enclosed in an airtight container of known volume for a known time, and the CO_2 evolved due to respiration was measured with the help of Gas Data Analyzer (GFM series 30-1/2/3, Gas Data Ltd., Coventry, UK) and expressed as ng CO_2 kg^{-1} s^{-1}.

Other parameters

Firmness was measured by using a portable Effigi penetrometer (FT-327) which record the pressure required to force a plunger into the flesh of fruit samples. Moisture content, total soluble solids, titratable acidity, ascorbic acid and ash content was estimated as per the method described by Ranganna [23]. Folin-Ciocalteu procedure given by Singleton and Rossi [24] was used for the estimation of total phenols and spectrophotometric method [25] was used for the lycopene estimation. For estimation of minerals, the samples were prepared as per the method suggested by Piper [26]. For the estimation of total phosphorus and nitrogen, Vanado Molybdate Phosphoric Yellow Colour Method and KjelTRON instrument was used respectively and calculated as per the method of AOAC [25]. For the estimation of Ca and K were estimated by flame photometer, whereas, Fe, Cu, Zn were estimated by Double Atomic absorption spectrophotometer.

Sensory evaluation

Sensory evaluation was performed at every third day intervals using the 9-point hedonic scale [27]. Ten panelists (5 males and 5 females), including trained and semi-trained staff members aged between 30-50 years as well as postgraduate students aged between 23-28 years from the Department of Food Science and Technology were given coded samples for three consecutive sessions individually for giving their views on appearance, flavour and overall acceptability. The analysis was done in sensory laboratory at controlled room temperature (20±2^{o}C).

Statistical evaluation

The data pertaining to initial physico-chemical characteristics obtained in this study were replicated five times and presented as mean± standard error. Tukey's HSD (honestly significant difference at $p < 0.05$) was used for significant mean separation (ranking sample means, largest to smallest) of SPNF and CHEM tomato quality parameters. Statistical evaluation was performed by using one-way analysis of variance (ANOVA) with a significance level $p < 0.05$. Completely Randomize Design (CRD) with three replications were used for analyzing quality parameters during storage, whereas, Randomized Block Design (RBD) was used for sensory analysis [28].

RESULTS AND DISCUSSION

Effect of MAP and storage conditions

PLW and Spoilage

Perusal of data in Table 2 showed a significant ($P<0.05$) effect of MAP, storage temperature and storage interval on PLW in tomato irrespective of farming system. It is evident from the data that with the progression of storage interval from 0 to 24 days, there was a consistent increase in PLW from 0.00 to 11.25 %, whereas, under different storage condition it goes only up to 8.26 %. The maximum change in PLW (8.26 %) was observed in tomatoes without MAP and stored at ambient condition (CHEM-AO) and minimum (1.74 %) was noticed in SPNF-RP tomatoes, which was statistically at par with the tomatoes stored in ZECC. It means, the produce stored under ZECC showed almost similar results as that of refrigerated conditions. However, the tomatoes stored under ambient conditions retained their freshness only up to 6 to 12 days, whereas, in comparison to this, tomatoes stored under ZECC retained freshness up to 12 to 18 days. Whereas, tomatoes without MAP under refrigerated conditions retained their quality characteristics up to 22nd day of storage and those with MAP under similar storage conditions remained their fresh-like characteristics even after 24th day. It was observed that ZECC has been found effective in reducing the average temperature from 28.01 to 20.37^{o}C and increased the average relative humidity from 68.22 to 83.86 % during one month of storage. Among farming system, SPNF tomatoes performed better and retained their quality characteristics for longer period under every storage conditions compared to CHEM tomatoes. Approximately 10 % of weight loss is considered as the threshold level and defined as an index to the end of commodity's shelf-life [29] and loss of 5 % will led to loss of freshness in the produce [30]. This loss in physiological weight is due to continuous respiration and transpiration processes within the fruit which leads to moisture loss from the commodity [31]. Higher difference in vapour pressure between fruit and environment accelerate the catabolic activities (breakdown of sugars and protein) and metabolic rate which led to weight loss of the fruit [14]. This might be the reason behind higher PLW in ambient storage conditions as compared to ZECC and refrigerated condition. Similar, results have been obtained by Islam and coauthors [19] and Islam and coauthors [30] who have successfully stored tomatoes under ZECC for a period of 29 and 24 days, respectively. Low temperature storage and ZECC storage showed significantly lesser change in PLW of the fruit as compared to ambient condition. Similar results have been reported by Dandago and coauthors [31] in tomato with variation in PLW from 0.163-19.57 %. The spoilage of fruits and vegetable is the outcome of ripening process and ethylene production. The spoilage of tomatoes was significantly ($p<0.05$) affected by modified atmospheric packaging and different storage conditions (Table 2). Generally, incidence of spoilage was reduced by the application of MAP and storage under low temperature. Minimum spoilage was observed in SPNF-RP (1.47%) followed by CHEM-RP, SPNF-RO and CHEM-RO, whereas, maximum incidence was noticed under ambient storage conditions (CHEM-AO). With the increase in storage period, the percentage of spoilage was also increased from 0.00 to 17.39 % up to 24 days. Tomato loses its marketable quality and freshness after 6 % of spoilage and become unappealing and shriveled. Tomatoes stored under ambient storage conditions retained the freshness up to 12 to 16 days, followed by zero energy cool chamber (from 18 to 20 days). However, refrigerated storage conditions in combination with MAP significantly ($p<0.05$) retained freshness and still remain fresh afterwards. In comparison to CF tomatoes, the SPNF grown tomatoes performed better in combination with low temperature storage and showed lesser incidence of spoilage for longer period of time. It was evident from the data (Table 2) that spoilage of tomato increased significantly with an increase in storage period. The major reason of spoilage of tomato during storage is the presence of higher moisture content which leads to infestation of microorganisms such as fungi on it [32]. Also the spoilage was majorly seen under ambient conditions which could be due to the conditions such as higher temperature and relative humidity conditions, which lead to proliferation of spoilage causing microorganisms at higher rates [33]. Synergistic effect of MAP and low temperature storage was observed in tomatoes irrespective of their farming system and statistically at par with tomatoes grown under ZECC and MAP conditions. Similar results were observed by Sinha and coauthors [34] in tomato fruits and Kumar and Thakur [35] in pear.

Table 2. Effect of MAP on physiological loss in weight and spoilage of tomato under different storage conditions

Storage interval (Days)	Storage conditions												
	PLW (%)												
	SPNF-AO	CHEM-AO	SPNF-AP	CHEM-AP	SPNF-ZO	CHEM-ZO	SPNF-ZP	CHEM-ZP	SPNF-RO	CHEM-RO	SPNF-RP	CHEM-RP	Mean
2	1.02	1.34	0.66	0.7	0.45	0.56	0.33	0.44	0.32	0.44	0.25	0.29	0.57
4	2.07	3.22	1.02	1.11	0.78	1.03	0.65	0.70	0.54	0.62	0.43	0.49	1.06
6	3.56	5.23	2.39	3.21	0.98	1.98	0.87	1.03	0.69	0.91	0.71	0.88	1.87
8	5.33	6.51	3.68	4.98	1.22	2.89	1.05	1.45	1.04	1.33	0.96	1.02	2.62
10	6.66	7.88	4.58	5.78	2.76	4.02	1.75	2.22	1.34	1.65	1.22	1.31	3.43
12	8.02	8.88	5.45	6.72	3.61	5.22	2.45	3.67	1.78	1.98	1.56	1.77	4.26
14	9.26	9.04	6.99	8.88	4.77	6.98	3.34	4.98	2.01	2.52	1.89	2.19	5.24
16	10.44	10.99	8.78	10.03	5.34	8.03	4.78	5.87	2.45	3.48	2.22	2.56	6.25
18	11.98	12.44	10.22	11.22	6.22	9.67	5.67	7.01	3.01	4.44	2.67	2.98	7.29
20	13.98	15.03	12.76	12.87	8.02	10.11	7.22	8.67	4.22	5.02	3.01	3.30	8.68
22	16.78	18.54	16.23	16.98	9.34	12.04	8.98	10.22	5.14	6.11	3.67	3.78	10.65
24	18.02	20.51	19.34	19.41	10.11	13.11	10.22	11.45	6.45	7.23	4.01	4.39	11.25
Mean	8.24	8.26	7.68	7.84	4.12	5.82	3.64	4.44	2.23	2.75	1.74	1.92	

Initial value = 0.00 %, $CD_{0.05}$ Treatment (T) =0.10, Interval (S)=0.05, Interaction (T × S)=0.09

Storage interval (Days)	Spoilage (%)												
	SPNF-AO	CHEM-AO	SPNF-AP	CHEM-AP	SPNF-ZO	CHEM-ZO	SPNF-ZP	CHEM-ZP	SPNF-RO	CHEM-RO	SPNF-RP	CHEM-RP	Mean
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.67	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
6	1.98	2.13	0.33	0.78	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.36
8	2.67	2.87	0.88	1.76	1.11	1.13	1.02	1.18	0.00	0.98	0	0.43	1.03
10	4.45	4.98	1.77	2.55	2.67	2.69	1.44	2.88	0.65	1.22	0.34	0.99	2.02
12	6.00	6.12	2.98	3.44	2.99	3.11	2.12	3.77	1.43	2.34	0.45	1.45	2.75
14	6.78	6.98	4.56	4.89	3.22	3.56	3.12	4.22	2.54	3.01	1.12	1.78	3.55
16	8.09	8.22	6.22	6.89	4.10	4.76	3.98	5.11	2.89	4.12	2.34	2.56	4.65
18	11.1	11.23	7.89	8.22	5.67	5.98	4.76	6.34	3.56	5.32	2.56	3.45	5.91
20	19.56	19.75	10.11	11.34	6.78	6.99	6.45	7.10	5.67	6.78	3.33	4.11	8.04
22	25.5	25.67	17.22	19.34	10.33	12.22	9.23	13.45	8.23	9.22	3.98	5.12	12.18
24	39.71	39.78	28.23	29.43	13.23	15.34	11.23	14.23	11.22	12.43	4.98	6.17	17.39
Mean	9.73	9.88	6.17	6.82	3.85	4.29	3.33	4.92	2.78	3.49	1.47	2.00	

Initial value = 0.00 %, $CD_{0.05}$, Treatment (T) =0.10, Interval (S) =0.05, Interaction (T × S) =0.09

Where, SPNF- Subhash Palekar natural farming, CHEM- Chemical farming system, AO- Without packaging and stored at ambient conditions, AP- packed in LDPE and stored at ambient conditions, ZO- without packaging and stored in ZECC, ZP- packed in LDPE and stored in ZECC, RO- without packaging and stored at refrigerated conditions, RP- packed in LDPE and stored at refrigerated conditions.

Firmness and Visual appearance

Firmness is an important quality attribute of fruits and vegetables, which has direct impact on consumer's acceptance, and it usually related to the control of weight loss in the fruit. Table 3 shows the effect of MAP and storage conditions on firmness of tomato during 24 days of storage. The statistics indicate that the firmness of the fruits decreased progressively under all storage conditions over the entire storage period of 24 days. But there was a significant difference in maintaining the firmness among all treatments. The lowest firmness was retained as 10.43 kg/cm^2 under CHEM-AO followed by SPNF-AO and CHEM-AP. Whereas, tomatoes stored under low temperature condition and MAP retained firmness as 11.05 and 9.11 kg/cm^2 in SPNF-RP and CHEM-RP for longest period of time (24 days). Data in the same table revealed that the change in firmness of low temperature stored tomatoes were statistically comparable to ZECC stored tomatoes. However, among tomato from different farming systems, SPNF tomato showed better firmness than that of CHEM tomatoes. SPNF grown tomatoes showed decrease in firmness from 15.85 to 12.98 kg/cm^2 which is statistically less increase compared to that in CF tomatoes (12.83 to 10.43 kg/cm^2). Irrespective of the farming system, the fruit stored under low temperature condition was found to be the best followed by ZECC and least preferred in ambient storage conditions. Sample stored under ZECC showed the variation in firmness from 11.63 to 14.29 kg/cm^2. However, the produce stored under ambient condition showed maximum change in firmness (10.43 to 13.31kg/cm^2) and loses its freshness in the first week of storage. Firmness of tomato is of utmost importance as it is associated with long shelf-life and good culinary quality of the produce. As fruits start to ripen, its cells become soft due to loss in turgor pressure and loss of water from it, causing physical damage to the cells [36]. As shown in Table 2, there was a gradual decrease in firmness with an increase in storage period. This might be due degradation of pectin by high activity of endopolygalactoronase enzyme which degrade the structural integrity of fruit at cellular level as well as due to moisture loss through transpiration. The enzymatic breakdown the pectin and de-esterification into shorter chains led to loosen the bonds between cell networks. Also, physical damage of fresh commodity during unit operation accelerates the growth of microorganism [35]. Also the fruit firmness decreases with fruit physiological maturity stage. The refrigerated stored tomatoes retained highest firmness, which could be due to low temperature which led to the inhibition of softening of fruit by suppressing rate of post storage ripening. Among treatments, slower rate of evaporation in the produce packed in polyethylene pouches stored under refrigerated storage conditions might be the reason for higher retention of firmness. Similar results were observed in tomato by Mutari and Debbie [37], Sinha and coauthors [34] and Shehata and coauthors [38] during storage under different conditions.

The data appended in Table 3 showed a significant effect of MAP and storage conditions on visual appearance of tomato. The scores recorded on 9-point hedonic scale varied from 5.58 to 7.57 from 0 to 24 days of storage and 4.98 to 8.12 under different storage conditions. SPNF-RP exhibited maximum scores followed by CHEM-RP and SPNF-RO. In comparison with low temperature storage, tomatoes stored under ZECC obtained statistically at par scores whereas, ambient condition tomatoes were least preferred by the sensory panelists. The change in visual appearance of tomato is directly related to change in firmness as well as pigment. As the colour development in tomato is very sensitive to temperature and rate of metabolic activities which led to faster conversion of plastid above 12 ℃ [19].

Table 3. Effect of MAP on firmness and visual appearance of tomato under different storage conditions

Storage interval (Days)	Storage conditions												
	Firmness (kg/cm^2)												
	SPNF-AO	**CHEM-AO**	**SPNF-AP**	**CHEM-AP**	**SPNF-ZO**	**CHEM-ZO**	**SPNF-ZP**	**CHEM-ZP**	**SPNF-RO**	**CHEM-RO**	**SPNF-RP**	**CHEM-RP**	**Mean**
0	17.61	14.76	17.61	14.76	17.61	14.76	17.61	14.76	17.61	14.76	17.61	14.76	16.19
2	17.39	14.57	17.34	14.59	17.37	14.64	17.45	14.67	17.5	14.71	17.59	14.73	16.05
4	17.04	14.17	17.1	14.23	17.22	14.34	17.23	14.4	17.45	14.62	17.5	14.67	15.83
6	16.12	13.28	16.45	14	17.14	14.04	17.18	14.1	17.23	14.42	17.41	14.44	15.48
8	15.3	12.22	15.36	13.24	16.03	13.89	16.58	13.91	17.00	14.23	17.23	14.31	14.94
10	14.32	11.78	14.37	12.46	14.91	13.1	15.23	13.45	16.45	14.03	17.04	14.07	14.27
12	13.65	10.67	13.78	11.76	13.94	12.27	14.92	12.98	16.03	13.25	16.78	13.67	13.64
14	13	10.12	13.03	11.02	13.41	11.34	13.44	11.89	15.15	12.37	16.23	13.28	12.86
16	12.02	9.22	12.45	10.45	12.89	10.78	12.91	11.03	14.67	11.89	15.92	12.65	12.24
18	10.22	8.11	11	10.04	11.78	10.12	12.04	10.56	13.81	11.02	15.04	11.07	11.23
20	9.03	7.24	10.12	8.95	11.15	9.13	11.46	9.45	12.02	10.25	14.33	10.39	10.29
22	7.22	5.45	8.23	6.49	9.98	7.78	10.68	7.98	11.11	9.19	12.29	9.7	8.84
24	5.78	4.01	6.13	5.18	6.23	5.63	7.03	6.34	7.79	8.21	11.05	9.11	7.30
Mean	12.98	10.43	13.31	11.29	13.97	11.68	14.29	11.92	15.06	12.53	15.85	12.83	

$CD_{0.05}$ Treatment(T)=0.03 Interval (S)=0.05, Interaction (T × S)=0.09

Storage interval (Days)	Visual appearance *												
	SPNF-AO	**CHEM-AO**	**SPNF-AP**	**CHEM-AP**	**SPNF-ZO**	**CHEM-ZO**	**SPNF-ZP**	**CHEM-ZP**	**SPNF-RO**	**CHEM-RO**	**SPNF-RP**	**CHEM-RP**	**Mean**
0	8.23	8.00	8.23	8.00	8.23	8.00	8.23	8.00	8.23	8.00	8.23	8.00	**8.12**
2	8.17	7.91	8.18	7.94	8.19	7.95	8.20	7.97	8.21	7.99	8.21	7.99	**8.08**
4	8.16	7.89	8.18	7.92	8.19	7.94	8.20	7.95	8.20	7.96	8.21	7.98	**8.07**
6	7.98	7.04	8.00	7.13	8.05	7.19	8.06	7.33	8.09	7.45	8.05	7.79	**7.68**
8	7.34	6.55	7.54	6.69	7.65	6.54	7.62	6.78	7.97	7.28	8.03	7.31	**7.28**
10	7.17	6.19	7.21	6.34	7.23	6.41	7.34	6.52	7.44	7.21	7.86	7.25	**7.01**
12	6.47	6.02	6.57	6.12	7.33	6.15	7.40	6.34	7.33	7.19	7.92	7.22	**6.84**
14	5.45	5.14	5.78	5.67	7.01	5.56	7.10	5.99	7.04	7.00	7.45	7.12	**6.36**
16	5.06	4.56	5.23	4.96	6.34	5.21	6.56	5.65	6.63	6.83	7.25	6.98	**5.94**
18	4.90	4.00	5.01	4.78	6.10	5.00	6.22	5.34	6.16	6.67	7.00	6.67	**5.65**
20	4.51	3.92	4.62	4.59	5.78	4.65	5.92	5.23	5.99	6.51	6.81	6.49	**5.42**
22	4.23	2.98	4.46	4.15	4.79	4.56	5.67	**5.20**	5.81	6.46	6.72	6.43	**5.12**
24	4.13	2.29	4.23	3.98	5.04	4.33	5.57	5.16	5.69	6.33	6.67	6.39	**4.98**
Mean	**6.29**	**5.58**	**6.40**	**6.02**	**6.92**	**6.11**	**7.08**	**6.42**	**7.14**	**7.14**	**7.57**	**7.20**	

$CD_{0.05}$, Treatment(T) =0.10, Interval (S) =0.05, Interaction (T × S) =0.09

Where, SPNF- Subhash Palekar natural farming, CHEM- Chemical farming system, AO- Without packaging and stored at ambient conditions, AP- packed in LDPE and stored at ambient conditions, ZO- without packaging and stored in ZECC, ZP- packed in LDPE and stored in ZECC, RO- without packaging and stored at refrigerated conditions, RP- packed in LDPE and stored at refrigerated conditions.

* Visual appearance scores on the basis of 9-point Hedonic scale

Respiration rate

Data on effect of different MAP packaging treatments on respiration rate of tomato fruit revealed an initial increase in respiration under all the treatments and storage conditions, which after reaching a maximum value started to decline during storage. Further, the increase in respiration rate of the fruits packed in the polymeric films bags from all treatments was evidently delayed, and especially in those cases where the packed fruits were stored under ZECC and refrigerated conditions as is evident from the Table 4.

The periodic evaluation also revealed that the fruits grown under SPNF system, packed in the polymeric films and stored under ZECC and refrigerated storage reached the peak values as late as after 20th day of storage indicating good storability and quality even after 24th day of the storage. The utilization of low temperature storage technology in conjunction with modified atmosphere inside LDPE bags might have resulted in slow respiration and thus delayed CO_2 peaks in such packages. Similar observations have also been reported by Kumar and coauthors [22] in pear fruits.

Table 4. Effect of MAP on the rate of respiration of the tomato fruits under different storage conditions

Storage interval (Days)	Storage conditions												
	Respiration rate (ng CO_2 kg^{-1} S^{-1})												
	SPNF-AO	CHEM-AO	SPNF-AP	CHEM-AP	SPNF-ZO	CHEM-ZO	SPNF-ZP	CHEM-ZP	SPNF-RO	CHEM-RO	SPNF-RP	CHEM-RP	Mean
0	0.00	0.00	0.00	0.00	0.00	0.00	0.0 0	0.00	0.00	0.00	0.00	0.00	0.00
2	25.16	24.71	15.09	16.23	17.45	19.55	12.34	14.23	12.34	15.45	10.12	13.34	15.27
4	43.08	42.88	29.12	37.83	25.56	28.67	16.21	25.45	16.45	20.65	14.09	15.54	25.51
6	78.28	78.13	40.23	55.64	36.76	42.64	25.76	36.56	24.65	31.32	18.22	22.23	36.66
8	95.15	89.03	58.45	74.57	48.87	67.86	36.67	51.65	32.32	38.44	26.21	32.45	50.26
10	86.76	85.33	76.56	97.91	67.43	89.71	46.12	67.43	38.12	45.67	34.67	41.67	67.43
12	74.12	73.09	90.78	88.43	78.89	97.24	55.61	76.87	47.47	56.76	42.11	49.71	73.61
14	65.10	67.00	82.96	77.32	88.02	78.23	68.14	89.45	61.10	67.61	55.31	64.12	67.88
16	57.73	55.01	77.53	65.76	98.91	65.54	76.23	92.67	72.25	79.31	64.23	76.13	74.19
18	47.13	46.29	62.91	53.43	84.33	53.48	82.11	78.43	89.38	85.15	82.10	89.26	80.27
20	34.09	33.02	45.52	43.56	66.24	32.55	88.14	67.34	80.76	86.27	80.14	85.43	66.79
22	22.15	20.98	43.87	32.66	44.53	24.81	85.20	39.25	72.89	76.72	76.12	72.38	44.20
24	10.12	9.92	25.34	21.33	33.06	18.11	65.11	26.76	66.24	63.85	68.10	61.49	29.91
Mean	47.13	46.29	45.52	53.43	48.87	42.64	60.36	51.65	47.47	56.76	42.11	49.71	

$CD_{0.05}$ Treatment(T)=0.32 Interval (S)=0.15, Interaction (T × S)=0.79

Where, SPNF- Subhash Palekar natural farming, CHEM- Chemical farming system, AO- Without packaging and stored at ambient conditions, AP- packed in LDPE and stored at ambient conditions, ZO- without packaging and stored in ZECC, ZP- packed in LDPE and stored in ZECC, RO- without packaging and stored at refrigerated conditions, RP-packed in LDPE and stored at refrigerated conditions.

Ascorbic acid and lycopene

The data presented in Table 5 depict the significant effect of different storage conditions and storage period on ascorbic acid content of tomato. Ascorbic acid content decreased gradually during entire storage period irrespective of farming system. The data showed a significant effects of storage interval and MAP in ambient, refrigerated and in ZECC storage conditions. With the storage period there was progressive decrease in ascorbic acid content 21.51 mg/100g (0 day) to 1.79 mg/100g (24th day) under different storage conditions. The decrease was noticed from 12.90 to 8.79 in case of SPNF tomatoes and 16.21 to 12.50 mg/100g in CHEM produce. Ascorbic acid content in fruits and vegetable is highly dependent on maturity and ripening. The enzymatic oxidation of ascorbic acid into dehydroascorbic acid during storage might be the reason of its loss [22]. The changes were more prominent in ambient conditions without packaging. Whereas, reduction in physiological processes inside tomato fruit due to refrigerated storage condition and ZECC led slower degradation of ascorbic acid. Similar results have also been published by Shehata and coauthors [38] in cherry tomato stored under cold storage conditions for 28 days. Whereas, due to the presence of modified atmospheric packaging over tomatoes which led to delayed the physiological and ripening process [2]. According to Borguini and coauthors [39] the organic tomatoes contained higher ascorbic acid (641.39 mg/100g) than conventional one (510.16 mg/100g).

Data on lycopene content of tomato fruits (Table 5) showed the significant effects of storage interval, MAP and storage conditions (ambient, refrigerated and ZECC) during entire storage period. Tomatoes grown under different farming system also shows significant effect on lycopene content. With the storage there was progressive increase in lycopene content from 1.42 to 4.17 mg/100g in case of different storage conditions. Whereas, among the samples stored under different storage conditions, it varied between 1.89 to 3.35 mg/100g. This might me due to the conversion of chloroplast to chromoplasts, which led to biosynthesis of carotenoids particular lycopene and catabolism of chlorophyll pigment. During ripening there is degradation of pigments such as lycopene and carotenoid which led to change in visual appearance of the fruit. Due to variation in temperature the synthesis of lycopene in the tomato can be interrupted which might be the reason of lesser changes at refrigerated and ZECC condition due to cooler temperature [14]. The synergistic effect of MAP and low temperature storage significantly delayed the ripening process as indicated from comparatively low lycopene content in these treatments. However, the modified atmospheric conditions inside the perforated polyethylene pouch obstruct the production of lycopene by creating suitable conditions for the fruit. Similar reduction in colour of tomatoes has been observed by Borguini and coauthors [39] and reported higher lycopene content in organically produce tomatoes (37.43 mg/100g) than conventional (40.80 mg/100g).

Table 5. Effect of MAP on ascorbic acid and lycopene of tomato under different storage conditions

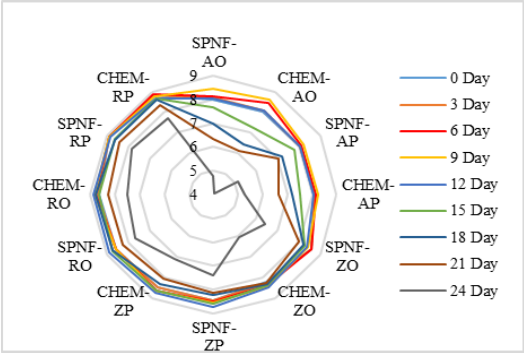
Storage interval (Days)	Storage conditions												
	Ascorbic acid (mg/100g)												
	SPNF-AO	**CHEM-AO**	**SPNF-AP**	**CHEM-AP**	**SPNF-ZO**	**CHEM-ZO**	**SPNF-ZP**	**CHEM-ZP**	**SPNF-RO**	**CHEM-RO**	**SPNF-RP**	**CHEM-RP**	**Mean**
0	23.76	19.25	23.76	19.25	23.76	19.25	23.76	19.25	23.76	19.25	23.76	19.25	**21.51**
2	22.27	17.13	23.09	17.23	23.24	18.56	23.3	18.6	23.32	18.77	23.55	19.13	**20.68**
4	20.08	15.34	22.18	15.78	22.45	16.89	22.88	16.93	22.98	18.01	23.13	18.78	**19.62**
6	18.28	**12.33**	20.56	12.99	20.98	13.02	21.04	13.56	21.78	17.44	22.78	18.24	**17.75**
8	**16.11**	11.03	18.23	11.56	19.29	12.46	19.78	12.78	19.22	16.12	20.98	17.31	**16.24**
10	14.12	9.33	16.87	**10.01**	18.00	11.10	18.33	11.6	16.34	14.23	19.34	16.66	**14.66**
12	12.98	8.03	**14.00**	8.22	14.78	**10.77**	15.00	10.79	14.02	11.16	18.02	15.98	**12.81**
14	11.21	7.29	12.67	7.34	12.99	9.37	13.04	9.45	11.11	8.56	16.22	12.87	**11.01**
16	9.23	5.99	10.77	5.78	**11.02**	8.98	11.96	**9.00**	10.04	6.45	13.24	10.22	**9.39**
18	7.23	3.25	7.56	3.75	8.03	5.87	**8.11**	5.93	9.22	4.22	11.94	8.76	**6.99**
20	4.29	3.02	5.00	3.14	6.22	3.01	6.45	3.45	7.28	**3.53**	9.42	7.03	**4.93**
22	2.45	2.11	3.18	2.67	4.35	1.23	4.37	2.38	**5.34**	2.45	7.22	6.23	**3.26**
24	0.45	0.23	2.10	1.02	3.06	0.78	3.14	0.67	3.23	0.87	**6.12**	**5.23**	**1.79**
Mean	**12.50**	**8.79**	**13.84**	**9.13**	**14.47**	**10.10**	**14.70**	**10.34**	**14.43**	**10.85**	**16.21**	**12.90**	

$CD_{0.05}$ Treatment(T)=0.07, Interval (S)=0.02, Interaction (T × S)=0.04

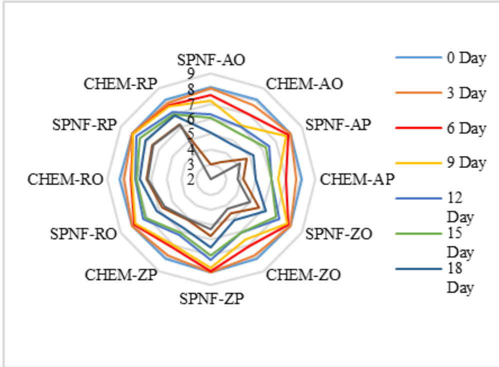
Storage interval (Days)	Lycopene (mg/100g)												
	SPNF-AO	**CHEM-AO**	**SPNF-AP**	**CHEM-AP**	**SPNF-ZO**	**CHEM-ZO**	**SPNF-ZP**	**CHEM-ZP**	**SPNF-RO**	**CHEM-RO**	**SPNF-RP**	**CHEM-RP**	**Mean**
0	1.20	1.63	1.20	1.63	1.20	1.63	1.20	1.63	1.20	1.63	1.20	1.63	**1.42**
2	**1.34**	1.71	1.30	1.70	1.29	1.68	1.28	1.65	1.25	1.65	1.23	1.64	**1.48**
4	1.56	1.78	1.45	1.73	1.43	1.71	1.40	1.68	1.35	1.67	1.33	1.66	**1.56**
6	**1.78**	**1.98**	1.55	1.80	1.52	1.79	1.48	1.76	1.40	1.70	1.36	1.69	**1.65**
8	**2.53**	2.67	1.69	2.45	1.61	2.41	1.57	2.36	1.51	1.78	1.45	1.73	**1.98**
10	**3.22**	3.01	**2.67**	**2.78**	1.89	2.77	1.88	2.45	1.82	1.94	1.67	1.88	**2.33**
12	3.45	3.56	**3.12**	3.04	2.12	**2.98**	2.04	2.69	1.98	2.05	1.93	1.96	**2.58**
14	3.78	3.80	3.56	3.56	2.45	3.45	2.39	2.98	2.00	2..34	1.98	2.04	**2.91**
16	4.02	4.12	3.60	3.98	**2.76**	3.78	2.34	**3.08**	2.26	2.67	2.05	2.17	**3.07**
18	4.11	4.56	4.01	4.11	3.01	4.98	**2.89**	4.56	2.56	2.87	2.19	2.34	**3.52**
20	4.17	4.78	4.17	4.70	4.08	4.67	3.19	3.98	3.08	**3.34**	2.45	2.87	**3.79**
22	4.23	4.92	4.20	4.87	4.14	4.79	3.54	4.05	**3.45**	3.58	2.77	3.01	**3.96**
24	4.39	5.03	4.27	5.00	4.20	4.87	3.78	4.17	3.70	3.82	3.01	3.77	**4.17**
Mean	**3.06**	**3.35**	**2.83**	**3.18**	**2.44**	**3.19**	**2.23**	**2.85**	**2.12**	**2.39**	**1.89**	**2.18**	

$CD_{0.05}$, Treatment(T) =0.4 Interval (S) =0.06, Interaction (T × S) =0.02

Where, SPNF- Subhash Palekar natural farming, CHEM- Chemical farming system, AO- Without packaging and stored at ambient conditions, AP- packed in LDPE and stored at ambient conditions, ZO- without packaging and stored in ZECC, ZP- packed in LDPE and stored in ZECC, RO- without packaging and stored at refrigerated conditions, RP-packed in LDPE and stored at refrigerated conditions



(a)



(b)

Figure 2. Effect of MAP on a) flavour and b) overall acceptability rating (on 9-point Hedonic scale) of tomato under different storage conditions.

Where, SPNF- Subhash Palekar natural farming, CHEM- Chemical farming system, AO- Without packaging and stored at ambient conditions, AP- packed in LDPE and stored at ambient conditions, ZO- without packaging and stored in ZECC, ZP- packed in LDPE and stored in ZECC, RO- without packaging and stored at refrigerated conditions, RP-packed in LDPE and stored at refrigerated conditions.

Flavour and Overall acceptability

Data presented in Figure 2 shows the significant effect of different storage conditions, period and MAP on sensory parameters such as flavour and overall acceptability of tomato. The results indicate decrease in overall acceptability of the tomato during storage, irrespective of farming system, whereas, flavour increase up to certain period then start degrading. The data revealed that in case of sensory characteristics, SPNF grown tomatoes were scored high and retained better quality for few more days than CF tomatoes. The maximum change in flavour score was recorded in CHEM-AO (decreased from 8.00 to 4.04) and minimum in SPNF-RP (decreased from 8.88 to 8.27). Similarly, significantly higher score for overall acceptability was obtained by SPNF-RP samples and it remained fresh like up to 24 days of storage. However, the least sensory scores were recorded in the samples, which were stored under ambient conditions without MAP. The loss in sensory characteristics especially flavor might be correlated with change in firmness of the fruit which led to change in cellular integrity. Also, due to continuous respiration the biochemical constituents changed from primary to secondary products caused change in flavour of the tomatoes. The synergistic effect of low temperature and MAP showed better scores of sensory characteristics followed by ZECC which might be due to slower rate of physiological processes inside the fruit. Similar results have been published by Roberts and coauthors [40] in tomatoes and recorded excellent quality attributes such as appearance and flavor up to 14 days of storage. Dew and coauthors [41] have also reported the similar results of sensory characteristics of tomatoes stored under ambient storage condition (23°C), an intermediate temperature (15°C) or the cooling chamber (12°C).

Comparative analysis of quality attributes

Physico-chemical and sensory characteristics

The physico-chemical characteristics and mineral content of SPNF tomato and CF grown tomato are presented in Table 6. Data pertaining to the physico-chemical and sensory characteristics of tomato revealed that SPNF tomatoes were superior in quality as compared to CF/CHEM tomatoes. The fruits of SPNF farming system are vigorous in size and weight as compared to CHEM. The weight of tomato grown through SPNF has larger size (diameter 5.03±0.08 cm and height 4.11±1.13 cm) and weight (85.83± 1.16 g) and having 10±1.11 fruits in one kg. Whereas, slightly smaller size (diameter 4.16±0.04 cm and height 3.24±0.09 cm) and weight (78.68± 0.78 g) with 12±1.10 fruits per kg has been found in CF tomatoes. Also, the firmness of SPNF tomatoes was also higher (17.61±0.04 kg/cm^2) than CHEM tomatoes (14.76±0.07 kg/cm^2). SPNF tomato contained higher total solids (7.84±0.06 %), TSS (4.56±0.02 °B), total sugars (3.12±0.09 %), reducing sugars (2.16±0.05 %), ascorbic acid (23.76±0.05 mg/100g), total phenols (36.02±0.14 mg/100g) and ash (1.17±0.05 %). Whereas, lesser moisture content (92.16±0.05 %), titratable acidity (0.37±0.06 %) and lycopene content (1.56 ±0.05 mg/100g) has been found in the same as compared to CF/CHEM tomatoes. Similarly, in case of sensory characteristics higher scores for appearance and texture were awarded to SPNF rather than CHEM (Table 6). Various studies have reported higher accumulation of bioactive compounds in SPNF tomato than chemically produce. The reason behind this might be due to the fact that, in organic manures micronutrients like nitrogen are present in lower amount which tends to slow release of it [42]. According to C/N theory, due to the limited availability of N, the plant metabolism shifts more towards carbon-containing compounds like starch, cellulose as well as non-N-containing secondary metabolites like phenolics and terpenoids [43].

Table 6. Comparison of physico-chemical parameters of SPNF and CHEM tomato

	Parameters*		**SPNF**	**CHEM**
Physico-chemical	Weight (g)		85.83± 1.13^a	78.68±0.81^b
	Size	Height (cm)	5.03±0.08^a	4.16±0.04^b
		Diameter (cm)	4.11±1.13^a	3.24±0.09^b
	Number of fruits per kg		10±1.11^a	12±1.10^a
	Firmness (kg/cm^2)		17.61± 0.04^a	14.76±0.07^b
	Moisture (%)		92.16±0.05^a	93.79±0.02^a
	Total solids (%)		7.84±0.06^a	6.21±0.05^a
	TSS (°B)		4.56±0.02^a	4.09±0.03^a
	Titratable acidity (%)		0.37±0.06^a	0.45±0.08^a
	Total Sugars (%)		3.12±0.09^a	2.79±0.07^a
	Reducing Sugars (%)		2.16±0.05^a	1.37±0.09^a
	Ascorbic acid (mg/100g)		23.76±0.05^a	19.25±0.03^b
	Lycopene (mg/100g)		1.54±0.05^a	1.63±0.02^b
	Total phenols (mg/100g)		36.02±0.14^a	31.02±0.11^b
	Ash content (%)		1.17±0.05^a	1.15±0.03^a
Sensory	Appearance		8.37 ±0.12^a	8.00 ±0.07^b
	Flavour		8.03 ±0.12^a	8.56 ±0.07^b
	Overall acceptability		8.12 ±0.12^a	8.04 ±0.07^a

* Values are mean of five determinations ± Standard Error.

The values followed by the same lower case letter, in the same row for individual parameter are not significantly different (Tukey's post hoc one-way test at p <0.05)

Mineral profile

The mineral profile showed (Table 7) that the tomatoes grown through SPNF have slightly higher content than other. There was significant difference in nitrogen, potassium, copper and iron content of tomato. SPNF tomatoes contained slightly higher content of these. SPNF tomatoes contained 3.33±0.06% nitrogen, 0.39±0.01% phosphorous, 3.17±0.04% potassium, 1.27±0.01 c mol(p+)/kg calcium and 6.50±0.12 % copper, 20.80± 0.36 % zinc and 286.67±6.64 % iron compared to CHEM tomatoes (potassium, 1.24±0.01 c mol (p+)/kg calcium, 5.73±0.09 % copper, 20 ± 0.58 % zinc and 278 ±2.98 % iron). On the basis of physico-chemical characteristics as well as mineral content it is evident that fresh tomatoes grown under SPNF system of farming performed better than those grown through CF system. Various researchers have also reported higher content of carbon, total nitrogen and extractable phosphorous, potassium, calcium, magnesium and other minerals from organic farm than that of conventional farms [44].

Table 7. Comparison of mineral content of SPNF and CHEM tomatoes

Parameters*	**SPNF**	**CHEM**
Nitrogen (%)	3.33±0.06^a	3.07±0.03^b
Phosphorous (%)	0.39±0.01^a	0.36±0.01^a
Potassium (%)	3.17±0.04^a	3.14±0.04^b
Calcium (c mol(p+)/kg	1.27±0.01^a	1.24±0.01^a
Cu (ppm)	6.50±0.12^a	5.73±0.09^b
Zn (ppm)	20.80±0.36^a	20.10±0.58^a
Fe (ppm)	286.67±6.64^a	278±2.89^b

* Values are mean of five determinations ± Standard Error

The values followed by the same lower case letter, in the same row for individual parameter (SPNF and CHEM produce) are not significantly different (Tukey's post hoc one-way test at p <0.05)

CONCLUSION

This study concludes that tomatoes grown under SPNF system packed in perforated LDPE and stored in refrigerated condition had the highest shelf-life of 24 days which was at par with ZECC stored tomatoes. In marketability point of view without much increase in PLW and spoilage, tomatoes can also be store for longer time in ZECC. Further it can be concluded that in high temperature and humidity conditions the chances of spoilage were highest which can be managed by creating modified atmosphere through low cost packaging material and storage under refrigeration conditions. So, tomato stored under refrigerated conditions and packed in LDPE with perforations was found best followed by zero energy cool chamber produce packed in polyethylene pouches. However, this study also suggests the wider acceptability of SPNF grown commodities with higher nutritional quality and marketable shelf-life with low input cost as comparison to chemical farming produce.

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