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COMPARATIVE EVALUATION OF SYNTHETIC AND PLANT-DERIVED PRESERVATIVES ON THE QUALITY AND SAFETY OF TOMATO PUREE

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ABSTRACT
Vegetable peels have been shown to have enormous potential for use as a source of safer, newer, better and effective antimicrobial and antioxidant compounds. Supercritical fluid extraction is a green technology for extraction of bioactive compounds from vegetable peels and offers improved extraction selectivity and efficiency. Consumer concerns about harmful effects of synthetic preservatives are increasing the need for development of natural preservatives. Supercritical fluid extracts of vegetable peels (pumpkin, turnip, and potato) were used in this study to preserve tomato puree and assess its shelf life over a 90-day period. Treatments included SP (puree having synthetic preservative), PPE (Puree having Potato + Pumpkin peel extract) and TPPE (Puree having Turnip+ Potato + Pumpkin peel extract). At 0, 30, 60, and 90 days of storage, the purees were examined for color, ascorbic acid, acidity, pH, total soluble solids, and antioxidant activity (TPC, DPPH). The findings demonstrated that TPPE was better in terms of antioxidant activity, vitamin C, DPPH, and total phenolic compounds. PPE and TPPE retained color, ascorbic acid, DPPH, and TPC better as compared to control during storage. TPPE also scored better in sensory evaluation for parameters like color, aroma, flavor and overall acceptability followed by PPE. The results revealed that vegetable peel extracts can be used as an efficient alternative to synthetic preservatives.

Keywords: Vegetable peels, supercritical fluid extraction, tomato puree, bioactive compounds

1. Introduction

Tomatoes, botanically known as Lycopersicon escullentum are cultivated and consumed worldwide, both in processed and raw forms. They contribute a sufficient quantity of antioxidants primarily phenolic compounds and carotenes in the daily meal. Carotenes consist of phytochemicals supporting good health and disease protection. According to epidemiological studies, tomatoes are rich source of antioxidants that have a number of health benefits, including protection from prostate cancer (Damian *et al.*, 2013). Although tomatoes are consumed as vegetables, they are classified as fruit based on their botanical characteristics. The watery part is 93 to 95 percent making up a major proportion while, the solid content ranges from 5.5 to 9.5 percent, with peel and seeds accounting for one percent of this solid content. This large variation in solid content is caused by irrigation, cultivars, soil and

environmental conditions. Citric acid is the main acid found in tomatoes, however there are trace amounts of tartaric, oxalic, and succinic acids as well. Antioxidants such as vitamin A, vitamin C, lycopene, flavonoids and carotenes are also abundant in tomatoes. Minerals like manganese, copper, zinc, and iron are also present in tomatoes (Nasir *et al.*, 2015). In Pakistan this plant grows in districts like Gujranwala, Karachi, Rahim Yar Khan, Sheikhupura and Swat. It is cultivated in December and January and ripens in April to June (Rehman, 2007). During the year 2014 to 2015 tomato was cultivated in an area of 60.7 thousand hectares giving a production of 570.6 tonnes (Agriculture Statistics Pakistan, 2014-2015). More than twenty percent of tomato production is wasted in Pakistan due to improper processing, preservation and marketing system. During harvest season, tomatoes are available in abundance reducing their price and ultimately farmer receives little return. While its availability is lower during the off-season, which drives up market prices. In cities, the need for tomato processing is increasing constantly (Safdar *et al.*, 2010).
Tomatoes are processed into tomato puree by concentrating tomato juice. Tomato puree is more beneficial for health as compared to other processed tomato products like sauce, ketchup and paste. Normally processing and cooking reduces nutritional value of vegetables and fruits, but tomato processing into puree results in an increase in availability of lycopene (Levy, 2009). The purpose of the present study is to assess the efficacy of SFE (supercritical fluid extracts) of vegetable peels (pumpkin, turnip, and potato) in tomato puree as natural preservatives and to investigate the nutritional value and storage stability of tomato puree during a storage period of 90-days.

2. Materials and Methods

2.1 Standards and Chemical Reagents

Chemicals and standards, such as Foilin-Ciocalteu reagent, gallic acid, and DPPH were obtained from Sigma-Aldrich (Tokyo, Japan) and Merck (Darmstadt, Germany).

2.2 Formulation of Vegetable Peel Extracts

Vegetable peels were procured from local vegetable processing units in Faisalabad. Vegetable peel extracts were prepared by supercritical fluid extraction (SFE) method. SFE-CO_2 was carried out in a pilot-scale system (Supercritical Fluid Technologies, USA) according to method described by Santos *et al.* (2021). Eighty gram (80 g) of each peel powder was loaded into a 500 ml extraction vessel. The extraction conditions were set at 25 MPa pressure, 40°C temperature and 120 min duration based on preliminary optimization studies. The extract was collected in a glass vial from the separator at controlled conditions. The extracts were stored in refrigerator until testing.

2.3 Formulation of Tomato Puree

Fresh tomatoes having optimum quality and bright red color were purchased from local vegetable market of Faisalabad. Formulation of puree and all the analysis were carried out in department of Food Science and Technology, Government College Women University, Faisalabad. Tomato puree was prepared according to the method explained by Romano *et al.* (2020). Fresh, ripe tomatoes were washed, blanched at 90°C for 1 min, peeled and deseeded. The tomatoes were then crushed in a blender to make a homogeneous pulp. The pulp was then strained through a sieve to take out any skin residues. Puree was divided into 3 batches, with the 1st one containing synthetic preservative (0.1% sodium benzoate). The other two batches contain natural preservatives one with 2.5% mixture of potato+ pumpkin peel extract and the other one having 2.5% mixture of turnip+ potato+ pumpkin peel extract. The puree was then filled into glass jars, sealed and held at refrigeration temperature for a period of 90 days. Analysis were carried out at an interval of 0, 30, 60 and 90 days.

2.4 Physicochemical Analysis of Tomato Puree

All puree treatments were evaluated for titratable acidity, sugar acid ratio, pH, ascorbic acid and total soluble solids according to AOAC (2019) standard procedures.

2.5 Total Phenolic Content of Tomato Puree
Total phenolic compound (TPC) of puree samples were determined by Folin-Ciocalteu reagent using the method described by Patras *et al.* (2009).

2.6 DPPH Free Radical Scavenging Activity of Tomato Puree
Antioxidant activity was measured through DPPH assay by following the method of Patras *et al*. (2019).

2.7 Color Analysis of Tomato Puree
The color analysis of puree samples was carried out through Hunter-Lab colorimeter having an aperture of 2.5 centimeter in diameter. The white and black tiles were used to calibrate instrument. Hunter Lab Units i.e., L^*, a^* and b^* were used to express color. Purée samples were carefully poured onto 50 mm plastic Petri plates to prevent air bubbles, and then they were set underneath the color meter's aperture (Patras *et al*., 2019).

2.8 Sensory Analysis of Tomato Puree
For sensory assessment nine-point Hedonic scale was used. Ten trained panelists were asked to evaluate color, flavor, aroma and overall acceptability of puree samples as described by Moreira *et al.* (2019).

2.9 Statistical Analysis
Statistical analysis was applied to obtained data using a 2-factor factorial CRD (completely randomized design) and Tukey’s test was used to compare means at 0.05 percent significant level by statistix software according to the method explained by Montgomery (2017).

3. Results and Discussion
3.1 pH of Tomato Puree
The pH is a key factor that affects the nutritional properties of tomato. Mean squares of pH showed non-significant variations within the treatments, storage and their interaction (Table 1). The mean values regarding pH of treatments and storage ranged from 4.31- 4.40. Vegetable peel extracts showed a slight change in treatments and storage. Treatment with synthetic preservative revealed highest decrease in pH (4.35-4.22) while treatment with turnip+pumpkin+potato peel extract demonstrated lowest decrease (4.36-4.32) in pH of tomato puree during storage. The decrease in pH of tomato purees is possibly due to increase in acidity of the tomato puree samples.
Alam *et.al.* (2018) investigated the effect of synthetic preservatives (potassium metabisulfite and sodium benzoate) on shelf life of tomato puree. pH analysis of puree showed a decrease in pH of all samples throughout storage with greatest decrease in control samples. While the preservatives treated sample exhibited stability or minor decrease in pH values.

Table 1. Effect of vegetable peels extract and storage on pH of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	4.39± 0.99	4.36± 1.01	4.30± 0.01	4.20± 0.59	**4.22± 0.05**
PPE	4.36± 0.05	4.34± 0.02	4.31± 0.04	4.27± 1.01	**4.32± 0.02**
TPPE	4.38± 0.01	4.37± 0.01	4.35± 0.01	4.32± 1.01	**4.35± 0.01**
Means	**4.38± 0.01**	**4.36± 1.01**	**4.32± 0.01**	**4.15± 0.49**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.2 Titratable acidity (TA) of Tomato Puree

Acidity is an important sensory attribute in tomatoes, followed by simple organic acids, such as the citric and malic (Kapoulas *et al.*, 2011). The mean values regarding TA of tomato puree of treatments ranged from 1.77 to 1.82% (Table 2). Mean value of titratable acidity at 0day was 1.75% and increased to 1.87% at 90th day of storage. Vegetable peel extracts revealed a non-significant change on treatments and storage days. Least increase in TA was observed in TPPE (33.3%turnip+ 33.3%pumpkin+33.3%potato). Results were almost stable at 30-day storage and then increased until the ninety day of storage.

Results obtained from present study are in accordance with Olaniran, *et al.* (2015) who observed that the titratable acidity of tomato paste with 2% ginger was fairly stable for the first 4 weeks and increased in most samples until the eighth week of storage. For tomato paste samples that contained the combination of 2% garlic and 2% ginger, the TA increased during the first 5 weeks of storage followed by a decrease to stable value for the remaining period of storage. Increase in titratable acidity of tomato paste may be due to organic acids produced by LAB (Lactic Acid Bacteria) and it may also be due to the oxidation of alcohol and aldehyde during processing. It has been reported that the amount of organic acids produced by LAB is influenced by storage temperature, the higher the temperature, the greater the increase in acidity. This is possible because of the increase in microbial growth and consequent increase in acid production.

Table 2. Effect of vegetable peels extract and storage on TA of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	1.75± 0.03	1.78± 0.06	1.84± 0.04	1.93± 0.99	**1.82± 0.04**
PPE	1.74± 0.03	1.77± 0.01	1.82± 0.05	1.86± 0.02	**1.79± 0.97**
TPPE	1.73± 0.01	1.76 ± 0.98	1.79± 0.04	1.82± 0.78	**1.77± 0.02**
Means	**1.75± 0.04**	**1.77± 0.01**	**1.81± 0.03**	**1.87± 0.01**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.3 Total Soluble Solids

Total soluble solids (TSS) are important for tomato puree as they help to determine the concentration of the puree, which is necessary to maintain its taste, color, and aroma. The mean values regarding TSS of treatments decreased from 9.83-8.79 °Brix (Table 3). The mean values regarding TSS of puree during storage (0-90 days) were found to be 9.76-9.83. Results showed that vegetable peel extracts did not show any significant change during storage.

Abbas *et.al.* (2023) carried out a study on replacement of synthetic preservatives with natural ones in food products. For this purpose, pigment derived from sweet red pepper was added in tomato paste in different amounts. A decrease in TSS was observed in all samples during a storage period of forty days. However, the decrease in TSS was more prominent in control sample than pigment added samples.

Table 3. Effect of vegetable peels extract and storage on TSS of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	9.80± 0.99	9.78± 0.01	9.71± 0.01	8.79± 1.00	**9.52± 0.01^{ab}**
PPE	9.83± 1.01	9.80± 0.01	9.76± 0.01	8.95± 0.99	**9.58± 0.01^{a}**
TPPE	9.86± 1.01	9.84± 0.01	9.81± 0.01	8.99± 0.59	**9.54± 0.03^{a}**
Means	**9.83± 0.11^{a}**	**9.80± 0.01^{a}**	**9.76± 0.01^{a}**	**8.79± 1.00^{b}**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.4 Ascorbic Acid

Mean squares of ascorbic acid showed significant variations within the treatments and storage but non-significant variation during storage interactions. The mean values regarding ascorbic acid of tomato puree of treatments ranged from 17.17 to 18.60 mg/100g (Table 4). Mean value of ascorbic acid at 0day was 18.25 mg/100g and decreased to 17.46 mg/100g at 90th day of storage. Vegetable peel extracts revealed a significant change during storage.

Sarkar *et al.* (2015) investigated the effect of sodium benzoate and potassium metabisulfite on ascorbic acid content of tomato pulp during a storage study of 150 days. Compared to untreated samples, treated samples had increased vitamin C retention for a longer period of time. Sodium benzoate depicted more efficient results as compared to potassium metabisulfite.

Table 4. Effect of vegetable peels extract and storage on Ascorbic Acid of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	17.60± 3.54	17.57±0.03	17.20± 0.02	16.66± 0.01	**17.17± 0.01^{a}**
PPE	18.62± 0.01	18.55± 0.01	18.39± 0.01	17.80± 0.01	**18.34± 0.01^{b}**
TPPE	18.89± 0.01	18.83± 0.01	18.77± 0.01	17.92± 0.02	**18.60± 0.01^{b}**
Means	**18.25± 0.02^{a}**	**18.31± 0.02^{b}**	**18.12± 0.01^{b}**	**17.46± 0.03^{c}**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.5 DPPH

The mean values regarding DPPH of treatments ranged from 76.54-78.86% (Table 5). The mean values regarding DPPH during storage (0-90 days) were found to be 76.58-79.10%. Maximum reduction in DPPH was found in puree sample with synthetic preservative.

Anwar *et al.* (2022) prepared tomato paste and added sodium benzoate and golden berry fruits and calyx extract as preservatives. During a storage study of 30 days' antioxidant activity of control samples reduced rapidly. While samples having sodium benzoate and natural extracts showed stability in antioxidant activity. Similarity between preservative potential of natural extract and sodium benzoate suggested the replacement of synthetic preservatives with the natural ones.

Table 5. Effect of vegetable peels extract and storage on DPPH of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	78.31± 5.03	78.15± 0.03	76.78± 3.46	74.94± 0.01	**76.54± 2.55^{b}**
PPE	79.40± 0.01	79.38± 0.01	78.60± 0.01	77.20± 0.01	**78.64± 0.02^{a}**
TPPE	79.61± 0.01	79.65± 0.01	78.63± 0.01	77.60± 0.05	**78.87± 0.01^{a}**
Means	**79.10± 0.01^{a}**	**79.06± 0.03^{a}**	**77.33± 0.05^{ab}**	**76.58± 0.04^{b}**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.6 Total Phenolic Content (TPC) of Tomato Puree

The mean values regarding TPC of treatments ranged from 48.15-52.20 mg GAE/100g (Table 6). The mean values regarding TPC of puree during storage (0-90 days) were found to be 48.73-51.03 mg GAE/100g. Vegetable peel extract showed significant changes during storage.

The increase in TPC after adding natural extracts is in line with Gerardi *et.al*. (2018) who added anthocyanin extracts in tomato puree to check their effect on phenolic content. Results demonstrated a significant increase in TPC of fortified puree as compared to control puree sample.

In another study Kausar *et.al*. (2024) calculated the TPC of carrot juice after addition of thyme, mint and moringa extracts. An increase in phenolic content was observed in juice samples having plant extracts. Control sample had minimum value of TPC while samples having higher percentages of extracts exhibited maximum values for phenolic content. TPC values of extract treated samples also showed stability during storage as compared to control sample. Thus, it can be concluded that plant based extracts can be used as an efficient alternative to synthetic preservatives.

Table 6. Effect of vegetable peels extract and storage on TPC of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	49.27± 0.01[bc]	49.23± 0.03[bc]	48.78± 0.98[c]	45.32± 0.98[d]	**48.15± 0.99[c]**
PPE	51.25± 0.05[ab]	51.21± 0.01[ab]	51.16± 0.01[abc]	49.90± 1.99[bc]	**50.88± 0.01[b]**
TPPE	52.64± 0.01[a]	52.61± 0.01 [a]	52.57± 0.01[a]	51.32± 1.49[abc]	**52.20± 0.02[a]**
Means	**51.03± 0.04[a]**	**51.01± 0.02[a]**	**50.83± 0.99[a]**	**48.73± 1.99[b]**	

SP=Synthetic preservative, PPE=50% pumpkin+50% potato. TPPE =33.3%turnip +33.3% pumpkin +33.3% potato

3.7 Color analysis of Tomato Puree

3.7.1 L* Value

The mean values regarding L* of tomato puree of treatments ranged from 29.25 - 29.75 (Table 7). The mean values regarding L* of storage (0-90 days) were found to be 29.72 – 29.29. Vegetable peel extracts revealed minimum decrease in L* during storage. Maximum decrease in L* value was observed in tomato puree with synthetic preservative.

The effect of potassium sorbate (KS) and ascorbic acid (AA) addition in pumpkin puree samples was investigated during a storage period of six weeks. Potassium sorbate prevented color loss in puree samples. This color protection could be caused by the oxidation of KS that consumes available oxygen and protect the oxidation of carotenoids. Furthermore, AA and KS acted synergistically and prevented color degradation in pumpkin puree (Gliemmo *et.al*., 2009).

Table 7. Effect of vegetable peels extract and storage on L* values of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	29.45± 1.04	29.37± 0.01	29.28± 0.01	28.91± 0.01	**29.25± 0.01[b]**
PPE	29.85 ± 0.01	29.80± 0.01	29.72± 0.04	29.44± 0.01	**29.70± 0.01[a]**
TPPE	29.89± 0.02	29.85± 0.06	29.77± 0.01	29.53± 1.03	**29.75± 0.01[a]**
Means	**29.72± 0.03[a]**	**29.67± 0.01[ab]**	**29.59± 0.04[ab]**	**29.29± 0.01[b]**	

SP=Synthetic preservative, PPE= 50% pumpkin+50%potato. TPPE = 33.3%turnip+ 33.3%pumpkin +33.3%potato

3.7.2 a* Value

The mean values regarding a* of tomato puree of treatments ranged from 25.73-29.96 (Table 8). The mean values regarding a* value of storage (0-90 days) were found to be 26.67-28.07. Vegetable peel extracts revealed increasing trend in a* during storage.

Hady *et al*. (2014) investigated the effect of carrot puree addition in strawberry jam to reduce discoloration. Characterization of carrot puree declared it a rich source of anthocyanins. Jam was stored for a period of six months. Results demonstrated that carrot puree worked as a natural colorant and increased the a* value of treated jam samples as compared to control. Moreover, carrot puree resulted in stability of a* values during storage.

Table 8. Effect of vegetable peels extract and storage on a* value of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	25.55± 1.01[f]	25.58± 0.01[f]	25.84± 0.01[ef]	25.97± 0.01[ef]	**25.73± 0.02[b]**
PPE	26.75± 1.00[e]	27.73± 0.01[d]	27.98± 0.02[cd]	28.10± 0.46[bcd]	**27.70± 0.01[ab]**
TPPE	27.72± 1.01[d]	28.82± 0.01[bc]	29.21± 0.01[ab]	29.89± 1.01 [a]	**29.96± 1.01[a]**
Means	**26.67± 1.01[c]**	**27.37± 0.93[b]**	**27.67± 0.02[ab]**	**28.07± 0.50[a]**	

SP=Synthetic preservative, PPE= 50% pumpkin+50%potato. TPPE = 33.3%turnip+ 33.3%pumpkin +33.3%potato

3.7.3 b* Value

The mean values regarding b* of treatments ranged from 18.27-18.56 (Table 9). The mean values regarding b* for storage (0-90 days) were found to be 17.44-19.16.

Al-Otabi *et.al*. (2023) formulated energy drink based on natural extracts (moringa leaf, caffeine and ginger rhizome) and date juice. The energy drink was stored for a period of 3 months and color changes were observed. Results depicted a slight decrease in b* values of energy drink containing natural extracts and date juice. While control sample exhibited a large decrease in b* value during storage. Among the enriched drinks, caffeine containing drink showed a more stable b* value as compared to other two treatments. The possible reason for this is presence of a large amount of antioxidant compounds.

Table 9. Effect of vegetable peels extract and storage on b* values of tomato puree

Treatments	Storage (days)				Means
	0	30	60	90	
SP	19.35± 0.02[a]	18.33± 0.01[b]	18.30± 0.01[b]	17.27± 0.99[b]	**18.56± 0.01[a]**
PPE	18.55± 0.03[b]	18.53± 0.01[b]	18.51± 0.01[b]	17.50± 1.01[b]	**18.27± 0.01[b]**
TPPE	18.59± 0.02[b]	18.57± 0.01[b]	18.56± 0.01[b]	17.56± 0.99[b]	**18.32± 0.02[b]**
Means	**19.16± 0.05[a]**	**18.47± 0.04[a]**	**18.45± 0.01[a]**	**17.44± 1.01[b]**	

SP=Synthetic preservative, PPE= 50% pumpkin+50%potato. TPPE = 33.3%turnip+ 33.3%pumpkin +33.3%potato

3.8 Sensory Analysis of Tomato Puree

The 9-point Hedonic scale method—9 being "like extremely" and 1 being "dislike"—was used to test the formulated puree samples (SP, PPE, TPPE) for sensory evaluation. Figure 1, 2, 3, and 4 demonstrate the sensory scores of all puree samples. TPPE was declared best in terms of taste, color, aroma, and overall acceptability followed by PPE. Storage study revealed that SP exhibited maximum decrease in sensory parameters as compared to extract treated puree samples. Present study revealed that natural extracts can preserve the product without negatively affecting its sensory attributes.

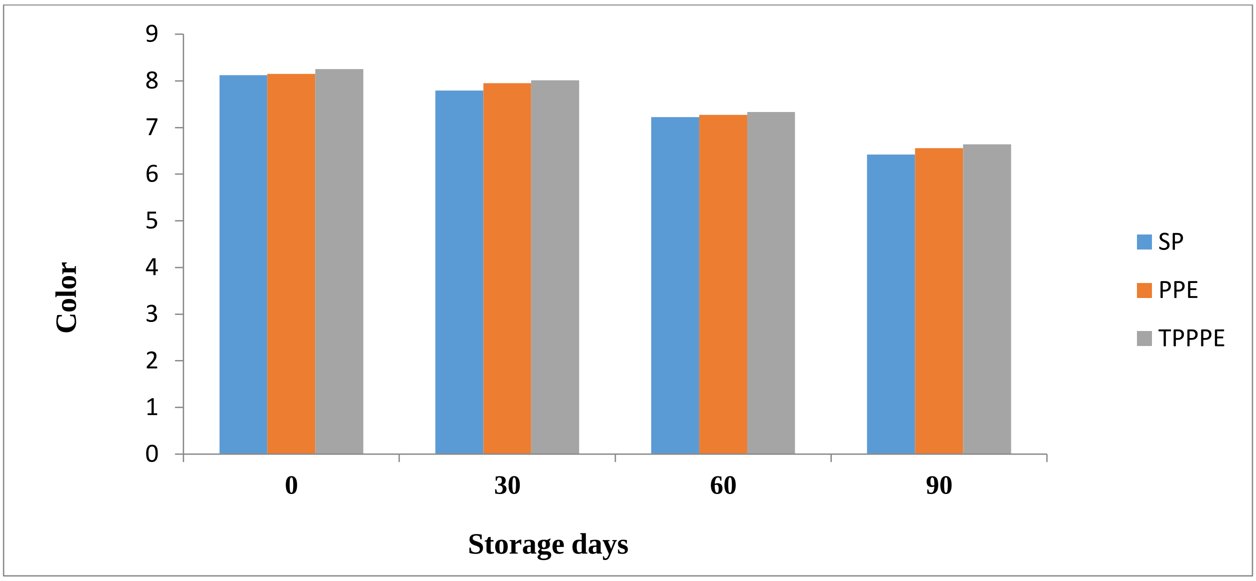

Figure 1. Color of Tomato Puree preserved with natural and synthetic preservatives

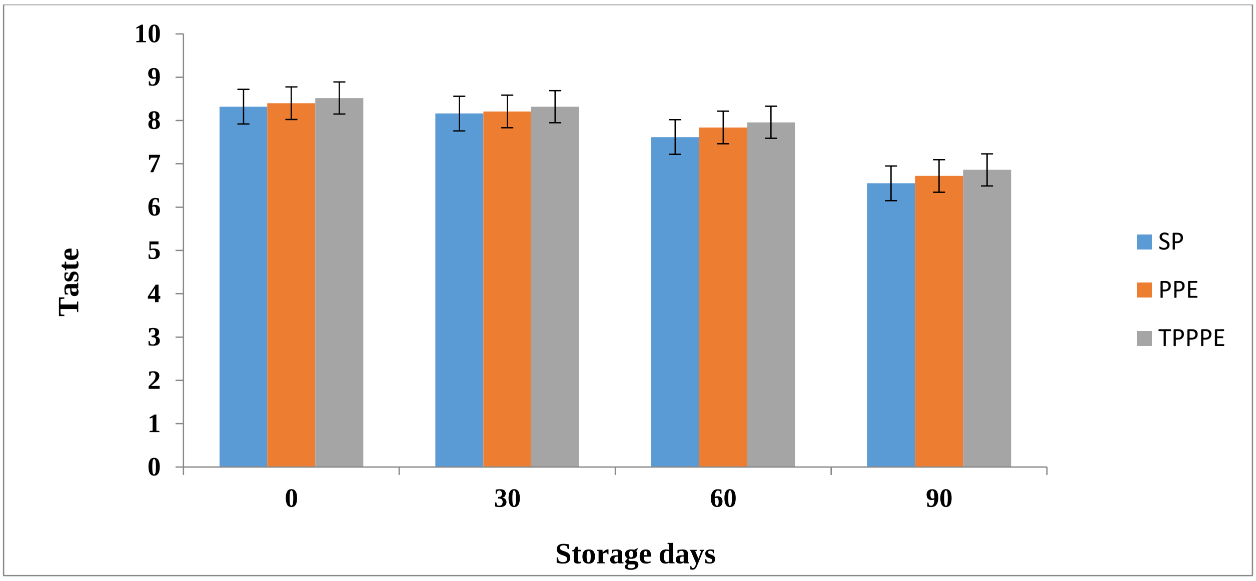

Figure 2. Taste of Tomato Puree preserved with natural and synthetic preservatives

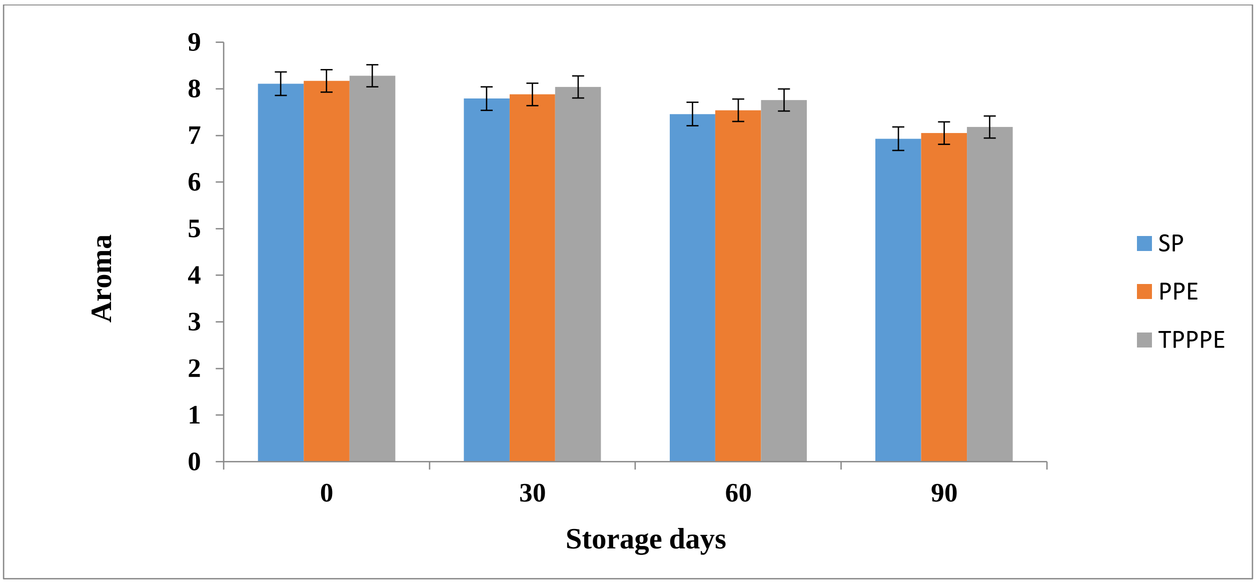

Figure 3. Aroma of Tomato Puree preserved with natural and synthetic preservatives

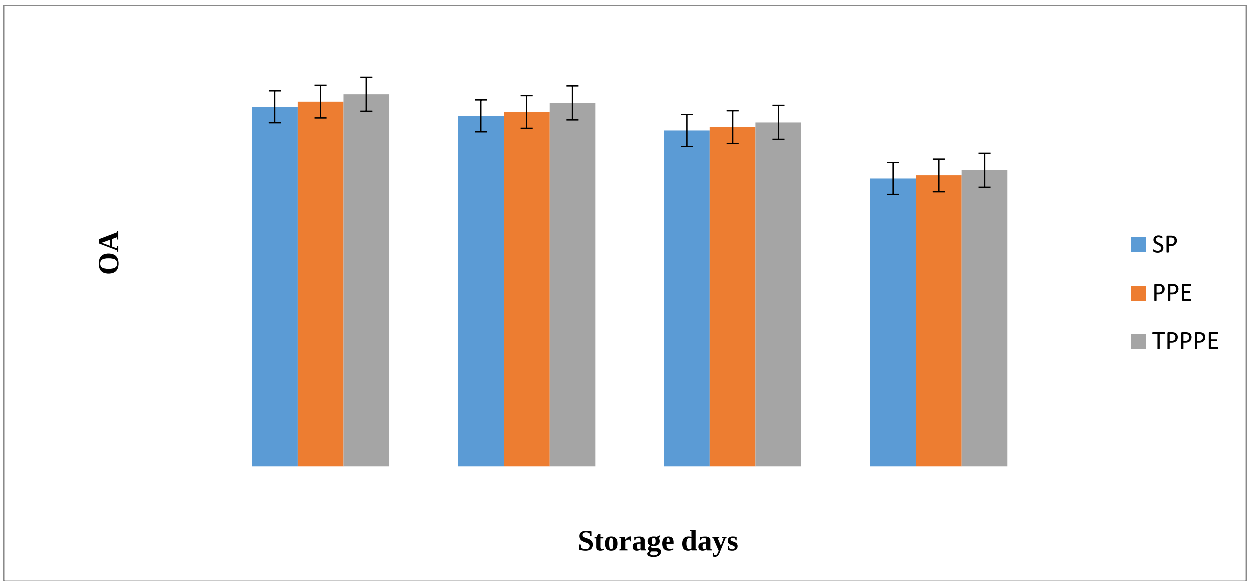

Figure 4. OA of Tomato Puree preserved with natural and synthetic preservatives

4. Conclusion

Preservative potential of vegetable peels i.e., turnip, pumpkin, and potato were evaluated in this study. Supercritical fluid extraction method was adopted to prepare peel extracts. The efficiency of these natural extracts was compared with natural ones. Results revealed that natural extracts can be used as an efficient alternative to synthetic preservatives without any compromise on nutritional and sensory qualities. Addition of natural extracts enhanced antioxidant activity, carotenoid and ascorbic acid content of tomato puree and maintained color, pH, acidity, during storage. Even for sensory analysis puree with natural extracts scored better than sodium benzoate (synthetic preservative) containing puree.

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