

RESEARCH ARTICLE

Probing the physicochemical characteristics of carrot sauce during storage

Muhammad Sameem Javed¹, Adnan Amjad^{1*}, Faiz-ul-Hassan Shah², Zulfiqar Ahmad², Aneela Hameed¹, Muhammad Junaid Anwar¹, Ammar Ahmad Khan³, Muhammad Amir¹, Muhammad Jawad¹, Muhammad Abrar⁴

1 Institute of Food Science and Technology, Bahauddin Zakariya University, Multan, Punjab, Pakistan, **2** Department of Food Science and Technology, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, Bahawalpur, Punjab, Pakistan, **3** University Institute of Diet and Nutritional Science, The University of Lahore, Lahore, Punjab, Pakistan, **4** Post Harvest Research Centre, Ayub Agricultural Research Institute Faisalabad, Faisalabad, Pakistan

* adnanamjad@bzu.edu.pk



Abstract

Globally, the prevalence of vit-A deficiency disorders i.e., xerophthalmia and nyctalopia is increasing especially in teenagers due to lifestyle shifts and undernutrition. This research was designed to develop carrot-supplemented tomato sauce to overcome vit-A deficiency and its related disorders. The carrot sauce was formulated with the addition of 50, 60, and 70% carrot pulp in tomato paste. The prepared sauce samples were tested for physical and biochemical changes in beta carotene (BC), lycopene, viscosity, pH, total soluble solids, titratable acidity, total plate count, and sensory parameters for 12 weeks. A non-significant effect of storage on BC, lycopene, and total soluble solids was observed. The total plate count, acidity, pH, and viscosity were influenced significantly. Sauce containing 60% of the carrot paste showed good sensory characteristics and 42.39 µg/g BC for the whole period of storage. It is concluded that carrot sauce can be used as tomato ketchup replacers to boost the overall quality of life by fighting against vit-A deficiency disorders.

OPEN ACCESS

Citation: Javed MS, Amjad A, Shah F-u-H, Ahmad Z, Hameed A, Anwar MJ, et al. (2022) Probing the physicochemical characteristics of carrot sauce during storage. PLoS ONE 17(11): e0273857. <https://doi.org/10.1371/journal.pone.0273857>

Editor: Umakanta Sarker, Bangabandhu Sheikh Mujibur Rahman Agricultural University, BANGLADESH

Received: October 16, 2021

Accepted: August 16, 2022

Published: November 16, 2022

Copyright: © 2022 Javed et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: All relevant data are within the manuscript and its [Supporting Information](#) files.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

1. Introduction

Chronic diseases due to micronutrient deficiencies are the major public health concerns [1]. With the increasing malnutrition, food safety issues, and pandemics health budgets are increasing in developing countries. According to Dawn Newspaper published on 28th August 2021 [2], only in Pakistan, has the health budget increased 49.6% (14.5 in 2020–21 to 21.7 billion Rupee). World Health Organization (WHO) reported that 53% of school-going children are suffering from the vit-A deficiency that leads to night blindness, distortions in color differentiation and anaemia. Vit-A deficiency is more prevalent in underdeveloped countries [3]. In Pakistan, 43% of the total population is facing vit-A deficiency with compromised physical activity among growing children. Recommended dietary intake of vit-A for children (6 to 12 years) is 250–350 µg as basal and 400–600 µg as safe, set by FAO/WHO [4]. Vit-A deficiency is the main cause of public health risk and needs attention to combat through supplementation and manufacturing of novel food products containing high bio-available vit-A contents [5].

In the era of processed foods across the cosmopolitan markets, the enrichment of the most popular products (i.e., sauces and ketchup, etc.) is a wise strategy to feed all age groups suffering from a vit-A deficiency. Different studies suggested that the average consumption of sauces varies between 17–25 g/day [6]. Tomato sauce is the most popular commodity formulated from tomato paste, vinegar, sweeteners, spices, flavoring agents, and some types of hydrocolloids including carboxymethyl cellulose [7]. Among the vegetables, carrots are rich in carotenoids that are the natural precursor of vit-A. Carrots contain 3.2 to 170 mg kg⁻¹ carotenoids, 24.97 µg/g BC and 21 to 775 mg kg⁻¹ vit-C [8]. Different carrot-based products i.e., smoothies, milk, chips, and yoghurt in which BC contents were 173.19 ± 1.02 µg/g, and carrot pomace supplemented tomato sauce were developed to reduce the risk of vit-A deficiency disorders [9]. The concentrations of BC do not change significantly after cooking as proved by the comparison of raw carrots with boiled and puree of carrots [10]. The digestion of carotenoids starts in the stomach and are absorbed via the intestinal brush border and move into the bloodstream as a chylomicron [11]. In Pakistan, Punjab province contributes the largest share of carrot production about 326.63 million tons. Punjab province contributes a major part (approximately 67%) in the economy of agriculture products where carrot production adds 2.8%, which is 68% higher compared to other provinces [12]. The most popular varieties i.e., red and purple colored contain higher amounts of vit-A in the form of α- and β-carotene. Bio-fortification of carrots improves the carotene content above 70% in various products [13]. The research was hypothesized that the supplementation of carrots to the sauce will enhance its nutritional profile and have the potential to reduce vit-A deficiency disorders.

In the country, carrot is mostly used to make fresh juice and carrot-based sweet dessert pudding (Gajar ka halwa) which are seasonal. Sauces are used round the year which can reduce the effect of seasonality and are a better option to supplement with more nutritious ingredients. The current study aimed to develop the carrots supplemented tomato sauce and to assess the effect of storage on its nutritional composition and shelf-life.

2. Material and methods

To optimize the sensory attributes of sauce, carrots and tomatoes were organically raised in the town of district Vehari, Pakistan. These vegetables were then harvested at horticultural maturity levels early in the morning. Vegetables were washed properly and transported in ice buckets to the food processing laboratory of the Institute of Food Science and Nutrition, Bahauddin Zakariya University Multan, Pakistan. In the laboratory, carrots were sorted, trimmed, and washed to remove inedible parts.

2.1. Preparation of carrot sauce

The carrot supplemented sauce was prepared by following the [14] with slight modifications. After coring the carrots were chopped and blended by laboratory-scale blender LB20ES at 9500 rpm to form a fine pulp. Tomatoes were washed and pulped by the same blender at variable speed. The sauce was prepared by using different concentrations of carrot and tomato pulp (Table 1) in a non-stick pan adding the measured quantities of onion, garlic, ginger,

Table 1. Replacement of tomato pulp by carrot paste in various concentrations.

Treatment	Carrot %	Tomato %
T ₀	0	100
T ₁	50	50
T ₂	60	40
T ₃	70	30

<https://doi.org/10.1371/journal.pone.0273857.t001>

coriander, red chillies, sugar, black pepper, sodium benzoate, salt, vinegar, and corn flour. After concentration, the pulp was homogenized using stainless steel homogenizer (colloid mill), sieved and heated to final consistency. The product was aseptically filled in glass jars and stored at room temperature for further analysis. All samples were analyzed for below mentioned physicochemical analysis at regular intervals of 15 days for the period of 3 months.

2.2. Physicochemical analysis

Proximate tests along with physicochemical and sensory analysis of the product samples were done by following the methods given in AOAC [15].

2.3. Determination of β -carotene

Almost 1g of representative sample was taken in a test tube and 5 mL acetone was added into it and kept for 15 min followed by intermittent shaking at high speed for 10 min. The test sample was then subjected to centrifugation for 10 min at 1370 relative centrifugal force. Two successive supernatants were separated in a test tube by adding 5 mL acetone in a test tube for each. The supernatant obtained was mixed with already obtained supernatant and filtered with Whatman filter paper No. 42. The absorbance of the sample was measured at 454 nm by using a spectrometer [16].

2.4. Determination of lycopene

Carrot sauce was weighed (5–10 g) in the beaker and acetone ether was used to extract the sample repeatedly until colorless. The sample was then transferred into a separating funnel, added 10–15 mL of petroleum ether and thoroughly mixed. Carotenoid pigments found in the acetone were transferred to the petroleum ether by diluting with distilled water and 5% sodium sulphate-containing acetone. The solution was then centrifuged at 3000 rpm using M-800 LT-161210 centrifuge machine. The supernatant was moved into the other funnel to achieve colorless sample and discard the acetone step. The petroleum ether was added to the 50 mL volumetric flask and diluted to label with petroleum ether and readings were observed at 503 nm by using spectrophotometer [15]. Lycopene present in the sample was calculated by given formula.

$$\text{Lycopene (mg/g)} = \frac{\text{Sample absorbance} \times \text{OD of sample} \times \text{vol.made up} \times 100}{1 \times \text{Wt.of sample} \times 1000}$$

$$\text{OD} = \text{Optical Density} = 3.1206$$

2.5. Viscosity determination

The viscosity of carrot sauce was determined by using LVT viscometer purchased from Brookfield engineering laboratories USA. The sample was weighed (200g) in a 250 mL beaker and attached the suitable spindle to the viscometer. The spindle was fully dipped into the sample at its described mark. Readings were taken from the dial when the needle was in the stationary phase after 5–6 rotations. To calculate the factor by using rpm and spindle number it was multiplied with readings [17]. The viscosity of carrot sauce was determined by the following formula:

$$\text{Dial reading} \times \text{Factor} = \text{Viscosity in cP}$$

$$\text{Factor} = \text{rpm} \times \text{spindle number}$$

$$\text{CP} = \text{centipoise (Unit of viscosity)}$$

2.6. Determination of plate count

For inoculum preparation, 1 mL from each sample was added in test tubes containing 4 mL of distilled water. Nutrient agar along with Petri-plates was sterilized in an autoclave (Hirayama HVA-85). The prepared media was then poured into plates in a vertical type of laminar airflow cabinet (CJ-1D). After streaking, the plates were incubated at 37°C in Memmert IF750 incubator for 48 hours and then bacterial colonies were counted by digital colonometer (FJ-2/FJ-3) in log cfu/mL by following the method described in AOAC [15].

2.7. Determination of total soluble solids (°Brix)

Total soluble solids of carrot sauce were measured by using a portable refractometer (Manufactured by MRC) at 20°C [15]. Before measuring, the prism was rinsed with distilled water and cleaned using tissue paper. The drop of sauce was placed on the prism and readings were taken.

2.8. Determination of pH

pH readings of carrot sauce were taken by using a digital pH meter (Model Iino-Lab720 Germany). The pH meter was calibrated by buffer solution of 4, 7 and 9. The sauce was taken in a 25 mL beaker and successive readings were directly noted from the screen by inserting the electrode in the sample as per the given protocols of AOAC [15].

2.9. Total titratable acidity

The titratable acidity of carrot sauce was determined by the simple titration method described in AOAC [15]. The samples were titrated by 0.1N sodium hydroxide against ascorbic acid and titratable acidity was calculated by using given equation

$$\text{Total Acid \%} = \frac{\frac{1}{10} \times \text{Eq.weight of acid} \times \text{Normality of NaOH} \times \text{Titer}}{10}$$

2.10. Sensory evaluation

Sensory evaluation of carrot sauce was conducted by a trained panel, students and staff members. The samples were served in the sensory analysis lab of the Institute of Food Science and Nutrition, Bahauddin Zakariya University under white light to each evaluator along with potato chips. The parameters like color, texture, taste, aroma, mouthfeel and overall acceptability were recorded by using a 9-point hedonic scale (extremely like = 9 and extremely dislike = 1) by following the method provided by Everitt [18].

2.11. Statistical analysis

Statistical analysis of data was carried out to check the level of significance by using statistical software statistix 8.1. Linear model was used to conduct analysis of variance of the data by applying a two-factor factorial design taking three replicates and two variables i.e., carrot: tomato concentrations (4 levels) and storage days (7 levels) under CRD at 0.05% confidence interval [19].

3. Results and discussion

3.1. Storage stability of β-carotene

The storage study of 12 weeks was conducted to evaluate the stability of β-carotene (BC) in carrot sauce. Data analysis depicted that BC contents were slightly influenced during the whole

Table 2. Storage study of 12 weeks to determine the β -carotene stability in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	5.75 ^k ±0.49	5.60 ^k ±0.51	5.25 ^k ±0.18	5.04 ^k ±0.15	4.98 ^k ±0.14	4.77 ^k ±0.18	4.33 ^k ±0.35
T ₁	43.02 ^{ej} ±2.60	41.96 ^{gj} ±1.70	41.27 ^{gj} ±1.51	40.50 ^{hj} ±1.12	40.04 ^{ij} ±0.93	39.81 ^{ij} ±0.78	38.56 ^j ±1.34
T ₂	49.97 ^{ad} ±2.80	49.14 ^{ac} ±3.10	48.20 ^{af} ±2.93	47.37 ^{bg} ±3.34	45.81 ^{ci} ±1.90	44.75 ^{di} ±0.90	42.39 ^{fj} ±2.17
T ₃	53.85 ^a ±3.27	52.22 ^{ab} ±3.11	51.42 ^{ac} ±2.96	50.72 ^{ad} ±1.71	49.56 ^{ad} ±0.66	49.05 ^{ae} ±1.11	46.39 ^{bh} ±2.83

<https://doi.org/10.1371/journal.pone.0273857.t002>

period of storage as shown in Table 2. BC contents were 10 times higher in a sample containing 70% carrot paste than control at the initial level of storage. The decrease in BC concentration was ~ 24.6% at the end of the 12-week storage study. The effect of treatments and storage was highly significant while a non-significant effect was observed for the interaction between treatments and storage. BC contents in T₁ containing 50% carrot paste were 43.02 ± 2.60 at 0 days of storage and observed 38.56 ± 1.34 at 12th week. A significant reduction in BC contents was linked with the effect of light, oxidative stress, temperature fluctuations and packaging [20]. The BC contents in the sauce sample containing 60% carrot paste were 49.97 ± 2.80 before storage which reduced to 42.39 ± 2.17 (15.16% reduction). A similar decreasing trend was observed in T₃ i.e., 46.39 ± 2.83 at the end of storage. Carotenoids are located inner to the cell membrane and are highly sensitive to oxidation when stored under ordinary conditions. The porosity of the cell membrane due to an increase in temperature may leach carotenoids [21]. BC stability studied by Mehrad *et al.*, [22] was also negatively correlated with storage conditions and encapsulation matrix.

3.2. Storage stability of lycopene

Lycopene is a bright red coloured compound that on heating isomerizes to give dark red colour. During the study period a non-significant effect of storage observed on lycopene contents while a highly significant difference was found among the treatments (Table 3). Maximum lycopene contents were noted in control and minimum in a sample containing 70% carrot paste. Lycopene contents approximately remained unchanged till the end of the storage period showing a 0.93% decrease. In the sample containing 50% carrot paste, the lycopene contents were 93.09 ± 0.36 µg/g at 0 days of storage and observed 92.12 ± 6.12 µg/g at the end of storage. Lycopene contents in T₂ of the fresh product were maximum which decreased ~1.71% till the end. Similar trends were observed for the sample containing 70% carrot paste. Smaller changes in the lycopene may be due to isomerization during heat processing and oxidation which convert the trans isomers into cis isomers thus reducing bioactivity. Light, heat, acids and various other factors contribute to the degradation of lycopene. The results were coherent with the findings of Li *et al.*, [23]. Martínez-Hernández *et al.*, [24] also observed a negative correlation between the days of storage and lycopene contents but not to a significant extent. According to

Table 3. Storage study of 12 weeks to determine the lycopene stability in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	153.26 ^a ±0.26	152.9 ^{ab} ±0.29	152.7 ^b ±0.23	152.5 ^{bc} ±0.18	152.2 ^{cd} ±0.21	152.0 ^{cd} ±0.18	151.83 ^d ±0.26
T ₁	93.09 ^e ±0.36	93.02 ^{ef} ±0.22	92.90 ^{ef} ±0.13	92.75 ^{efg} ±0.11	92.56 ^{fgh} ±0.19	92.31 ^{gh} ±0.15	92.12 ^h ±6.12
T ₂	87.05 ⁱ ±0.26	86.90 ^{ij} ±0.13	86.66 ^{ij} ±0.28	86.42 ^{jk} ±0.32	86.00 ^{kl} ±0.18	85.79 ^l ±0.11	85.56 ^l ±4.14
T ₃	79.33 ^m ±0.51	78.93 ^{mn} ±0.50	78.68 ^{no} ±0.55	78.50 ^{no} ±0.50	78.27 ^{opq} ±0.39	78.18 ^{pq} ±0.33	78.00 ^q ±0.26

<https://doi.org/10.1371/journal.pone.0273857.t003>

Table 4. Storage study of 12 weeks to determine the titratable acidity in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	1.85 ^e ±0.03	1.91 ^d ±0.02	1.94 ^d ±0.01	2.02 ^c ±0.04	2.08 ^b ±0.03	2.12 ^{ab} ±0.03	2.14 ^a ±0.04
T ₁	1.52 ⁿ ±0.02	1.54 ^{mn} ±0.01	1.57 ^{klm} ±0.02	1.59 ^{ijk} ±0.01	1.64 ^h ±0.02	1.68 ^g ±0.02	1.69 ^f ±0.02
T ₂	1.45 ^r ±0.02	1.50 ⁿ ±0.01	1.54 ^{mn} ±0.01	1.55 ^{lm} ±0.01	1.58 ^{jkl} ±0.02	1.6300 ^{hi} ±0.01	1.7133 ^{fg} ±0.015
T ₃	1.40 ^p ±0.025	1.44 ^{op} ±0.01	1.45 ^r ±0.02	1.51 ⁿ ±0.02	1.58 ^{jkl} ±0.02	1.62 ^{hij} ±0.03	1.68 ^g ±0.03

<https://doi.org/10.1371/journal.pone.0273857.t004>

the data reported by Liang *et al.*, [25] the minor degradation in lycopene present in tomato pulp can be prevented by forming emulsion using different oils i.e., olive oil.

3.3. Effect of storage on titratable acidity of carrot paste supplemented tomato sauce

Titratable acidity (TA) is a measure of total acids present in a product and is responsible for colour, taste and microbial stability. Storage and treatments had a highly significant effect on the TA. From Table 4, it is evident that the TA of carrot sauce was slightly changed with the storage time. In the control sample, the TA of the sauce was changed significantly with the increase in storage period and was 2.14 ± 0.04 at the 12th week. TA of carrot sauce having 50% carrot paste increased to 10% during three months of storage period and was 1.52 ± 0.02 at the initial level which increased at the end of storage. In treatment having 60% carrot paste the value of TA changed from 1.45 ± 0.02 to 1.71 ± 0.015 during the period of 12 weeks. In T₃ having 70% carrot paste the value of TA at 0 days was 1.40 ± 0.025 which increased to 1.45 ± 0.02 , 1.58 ± 0.02 and 1.68 ± 0.03 at 4th, 8th and 12th week. This positive correlation between TA and storage time might be due to the breakdown of polysaccharides, sugars oxidation and degradation of pectic substances. A higher amount of salts in the carrot sauce may be another reason for increasing of TA [26]. A study conducted by Pourfarzad & Derakhshan [27] on hazelnut sauce also showed that TA increased during storage while using guar gum and tragacanth as a thickening agent.

3.4. Changes in pH of carrot paste supplemented tomato sauce

Changes in pH value of carrot sauce during the period of three months are given in the mean Table 5. A decreasing trend in pH of the sauce was observed throughout the storage period. The effect of treatments was significant on the pH of the sauce while the interaction between storage and treatments was non-significant. In the control sample the value of pH at the start of storage was 3.68 ± 0.08 which decreased to 3.55 ± 0.03 at the 4th week of storage and this trend continued till the end with a value of 3.37 ± 0.02 . This reduction in pH of the sample having 50% carrot paste was noticed from 3.81 ± 0.02 at the initial level to 3.66 ± 0.08 and 3.48 ± 0.02 at the 6th and 12th week of storage respectively. In T₂ pH at the initial level of

Table 5. Storage study of 12 weeks to determine the pH stability.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	3.68 ^{a-g} ±0.08	3.58 ^{a-j} ±0.03	3.55 ^{d-j} ±0.03	3.47 ^{g-j} ±0.06	3.44 ^{hij} ±0.04	3.39 ^{ij} ±0.02	3.37 ^j ±0.02
T ₁	3.81 ^a ±0.02	3.79 ^{ab} ±0.02	3.72 ^{a-e} ±0.3	3.66 ^{a-h} ±0.08	3.59 ^{a-j} ±0.04	3.56 ^{c-j} ±0.03	3.48 ^{fj} ±0.02
T ₂	3.55 ^{d-j} ±0.60	3.78 ^{abc} ±0.08	3.74 ^{a-e} ±0.6	3.67 ^{a-g} ±0.3	3.61 ^{a-i} ±0.04	3.52 ^{e-j} ±0.12	3.47 ^{g-j} ±0.12
T ₃	3.76 ^{a-d} ±0.10	3.73 ^{a-f} ±0.10	3.66 ^{a-h} ±0.1	3.63 ^{a-h} ±0.1	3.57 ^{b-j} ±0.14	3.54 ^{d-j} ±0.14	3.47 ^{g-j} ±0.14

<https://doi.org/10.1371/journal.pone.0273857.t005>

Table 6. Storage study of 12 weeks to determine the total plate count in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	1.48 ^k ±0.22	1.54 ^{jk} ±0.25	1.58 ^{jk} ±0.23	1.59 ^{jk} ±0.19	1.63 ^{jk} ±0.19	1.66 ^{jk} ±0.19	1.79 ^j ±0.14
T ₁	2.37 ⁱ ±0.29	2.44 ^{hi} ±0.29	2.42 ^{hi} ±0.31	2.46 ^{hi} ±0.26	2.55 ^{hi} ±0.25	2.62 ^{hi} ±0.23	2.70 ^{gh} ±0.24
T ₂	2.98 ^{fg} ±0.1	2.96 ^{fg} ±0.05	3.04 ^{ef} ±0.06	3.11 ^{def} ±0.07	3.20 ^{c-f} ±0.06	3.32 ^{a-e} ±0.07	3.40 ^{a-d} ±0.07
T ₃	3.17 ^{c-f} ±0.06	3.25 ^{b-f} ±0.03	3.28 ^{a-e} ±0.06	3.35 ^{a-d} ±0.08	3.44 ^{abc} ±0.06	3.49 ^{ab} ±0.08	3.55 ^a ±0.06

<https://doi.org/10.1371/journal.pone.0273857.t006>

storage was 3.55 ± 0.60 which increased till the 4th week and then gradually decreased to 3.47 ± 0.12 at the end. But in the sample having 70% carrot paste the pH showed a decrease of 7.7% till the end of storage. Prakash *et al.* [28] reported a pH range of 3.25 to 3.65 in acerol tomato ketchup. Moringa root supplemented tomato sauce also indicated similar results i.e., 4.62 ± 0.05 which reduced with the progression of storage [26]. The changes in pH of the carrot sauce may be correlated with microbial invasion and oxidative breakdown of complex compounds thus releasing organic acids. Environmental factors also contribute to biochemical changes during storage of the product.

3.5. Effect of storage on total plate count of carrot supplemented tomato sauce

The correlational study between different treatments and storage time indicated that the highest total plate count (TPC) was observed in treatment having 70% carrot paste at 12th week of storage. From the Table 6 it is evident that the minimum value was found in control at the start of storage which increased at 12th week. A similar increasing trend was seen in T₁ during the storage showing an elevation of 12.22%. The value of TPC in treatment having 60% carrot paste was noted 2.98 ± 0.1 Log CFU/g at 0 days and showed a highly significant increase during the whole period i.e., 3.40 ± 0.07 Log CFU/g at 12th week. According to the set parameters by WHO/FAO 7 Log CFU/g of TPC is safe for human consumption with exception of *Salmonella*, *E. coli* and *coliforms* [29]. The results were in coherence with the previous study of Sucharitha *et al.*, [30] who reported an increase in TPC of tomato preserve from 2.27 to 8.15 for one month. Microbial growth may be occurring due to the different thickening agents and the type of storage condition. The presence of carbohydrates may also support microbial growth [31].

3.6. Variability in total soluble solids (°Brix) of carrot supplemented tomato sauce during storage

During three months, treatments and storage have a highly significant effect on total soluble solids (TSS) as depicted in Table 7. The effect of treatments and the interaction between storage and treatments was highly significant. The lowest value was observed in the control sample

Table 7. Storage study of 12 weeks to determine the total soluble solids in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	24.79 ^j ±1.23	24.93 ^j ±1.39	24.89 ^j ±1.83	25.03 ^j ±1.28	24.91 ^j ±2.19	24.95 ^j ±1.83	25.18 ^{ij} ±1.31
T ₁	25.93 ^{fg} ±1.41	26.15 ^f ±1.82	25.70 ^{gh} ±1.03	25.75 ^{gh} ±1.71	25.51 ^{hi} ±1.48	25.67 ^{gh} ±1.29	25.98 ^{fg} ±1.52
T ₂	26.87 ^{de} ±2.00	27.03 ^d ±1.45	26.89 ^{de} ±1.90	27.01 ^d ±1.52	26.72 ^e ±1.29	27.17 ^d ±1.62	27.05 ^{de} ±1.91
T ₃	27.95 ^c ±1.75	28.07 ^c ±1.69	27.96 ^c ±2.15	28.25 ^c ±1.84	27.93 ^c ±1.45	28.69 ^b ±1.72	29.11 ^a ±1.87

<https://doi.org/10.1371/journal.pone.0273857.t007>

Table 8. Storage study of 12 weeks to determine the viscosity in treatments.

Treatments	Storage weeks						
	0	2	4	6	8	10	12
T ₀	2286.0 ^a ±52.37	2100.7 ^{bc} ±138.91	2014.7 ^{cd} ±115.94	1925.7 ^{def} ±51.05	1721.7 ^{gh} ±71.30	1515.7 ^{ij} ±3458	1312.3 ^{kl} ±50.64
T ₁	2184.6 ^{ab} ±36.75	1984.7 ^{cde} ±175.92	1848.3 ^{efg} ±95.37	1596.7 ^{hi} ±188.21	1512.0 ^{ij} ±29.86	1296.7 ^{kl} ±63.10	1092.7 ^{mno} ±227.06
T ₂	1789.3 ^{fg} ±66.50	1700.7 ^{gh} ±58.77	1596.7 ^{hi} ±73.56	1285.0 ^{kl} ±34.39	1214.7 ^{lm} ±46.52	1023.7 ⁿ ±161.55	789.0 ^o ±147.40
T ₃	1589.7 ^{hi} ±86.23	1511.7 ^{ij} ±5095	1377.7 ^{jk} ±38.39	1218.7 ^{klm} ±65.59	986.0 ⁿ ±9.53	736.0 ^o ±40.85	736.0 ^o ±95.91

<https://doi.org/10.1371/journal.pone.0273857.t008>

at the initial level of storage which increased gradually till the end. In treatments having 50 and 60% carrot paste, the value of TSS was not changed during the whole period. A slight change was observed in T₃ and values changed from 27.95 ± 1.75 to 29.11 ± 1.87 . Environmental factors and acid hydrolysis of polysaccharides are considered major contributors to fluctuations in TSS [32]. The value of TSS for strawberry ketchup ranged from 26.1 to 27.3 [33] and TSS reported for Brazilian ketchup was in the range of 24.36 to 33.35 [34].

3.7. Effect of storage on the viscosity of sauce

All the analyzed samples of different treatments showed that the viscosity of carrot sauce decreased during storage. Initially, the control sample was more viscous than other treatments i.e., 2286.0 ± 52.37 which reduced to 1312.3 ± 50.64 at the end of storage (Table 8). Statistical analysis revealed that a significant difference exists between viscosity, storage weeks, and treatments ($P < 0.05$). A decreasing trend was observed in all treatments i.e., in T₃ viscosity was 1589.7 ± 86.23 at 0 storage week which gradually reduced to 736.0 ± 5.91 at the 12th week. Xu *et al.* [35] reported that different processing methods and storage affect the viscosity of different tomato-based products. Conversions of pectic polysaccharides present in carrots are contributing to a decrease in viscosity. The results showed a similarity when different thickening agents were used to optimize the moisture retention properties of tomato sauce [36].

3.8. Sensory attributes of the sauce

3.8.1. Colour changes during storage of carrot supplemented tomato sauce. Sensory color recorded by the panelists indicates that the highest score was given to the sample having 70% carrot paste followed by control. Variation in color values among the treatments is prominent while a non-significant effect of storage was noted (Fig 1). The sensory color increased slightly till the second week of storage and then continued decreasing. The declining pattern might be due to the oxidation and isomerization of β -carotene during storage. The reducing trend was observed in all the treatments but stability was noted in T₃. Li *et al.* [23] linked the color changes with the degradation of lycopene and Maillard reactions. Data reported by Kaur *et al.* [37] stated that different processing and storage conditions affected the color of the tomato hot pot. Consequentially T₃ was best among the others with more nutritional value and β -carotene contents.

3.8.2. Textural variations in carrot supplemented tomato sauce during storage. Textural evaluation of the carrot sauce showed that more smoothness was observed in control and T₃ at the start of storage. In the sample having 50 and 60% carrot paste sensory texture was significantly different from the control and with 70% carrot paste, also a similar was observed with the progression of storage. Textural instability was more in samples containing carrot paste as compared to control (Fig 2). A slight clumping was observed leading to textural changes. According to Szczesniak, [38] textural changes in plant-based products are due to the breakdown of pectic substances and polysaccharides which on disintegration may contribute

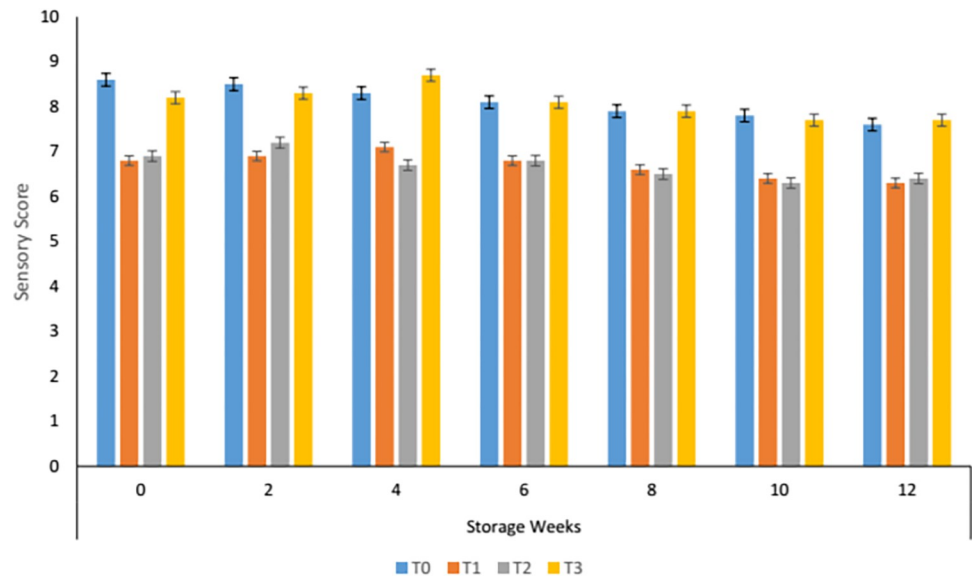


Fig 1. Sensory colour of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g001>

to clump formation to some extent. Similar results were reported by Kamsina & Anova, [39] when Kandis acid was used in the formulation of tomato sauce.

3.8.3. Effect of storage on the taste of carrot supplemented tomato sauce. The sensory taste of the carrot sauce was significantly different among the treatments. A comparable taste score was evaluated in the control sample and T₃ while in T₁ and T₂ this score was not accepted by the panelist (Fig 3). With the progression of storage, taste improved in the sample having 70% carrot paste till the 4th week and then starts decreasing gradually but found more satisfactory than the rest of the treatments and control samples. Nkhata & Ayua [40] reported that taste was negatively influenced after one month when stored at 30°C while no adverse

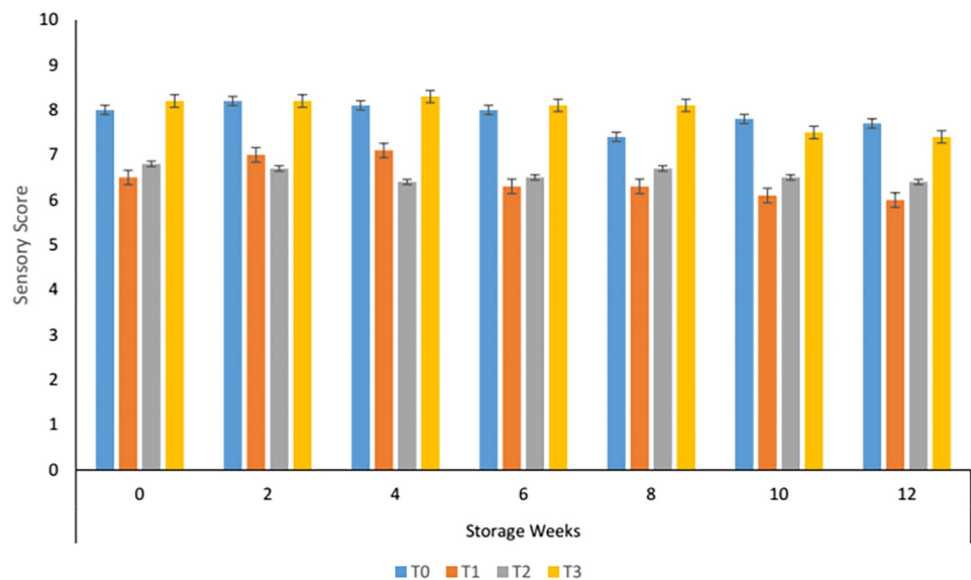


Fig 2. Texture of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g002>

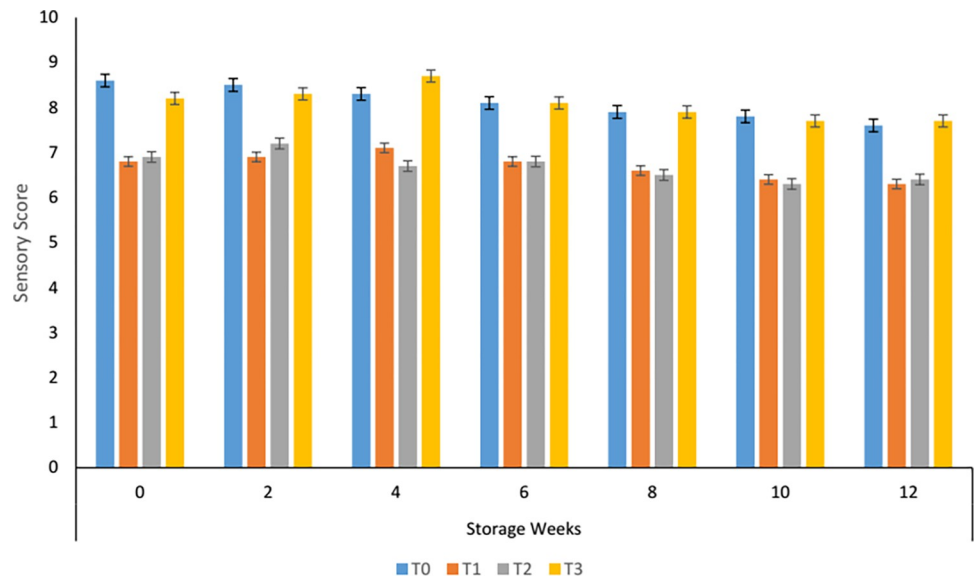


Fig 3. Taste of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g003>

effect was found at 6°C. Similar, results were observed for the moringa root supplemented tomato sauce [26].

3.8.4. Effect of storage on mouth feel of carrot supplemented tomato sauce. Panelist scores depicted that the mouth feel of carrot-based sauce increased till the 2nd week and then start decreasing progressively. It is clear from Fig 4. That among the treatments T₃ was best when compared with control and found satisfactory till the end of storage. The treatments had 50 and 60% of carrot paste were significantly different ($P < 0.05$) from control and T₃. Xu *et al.* [41] monitored a significant reduction in mouth feel while studying the post-harvest changes in tomatoes. Landy *et al.* [42] also found that there was no correlation between mouthfeel and storage days but environmental conditions negatively influenced mouth feel.

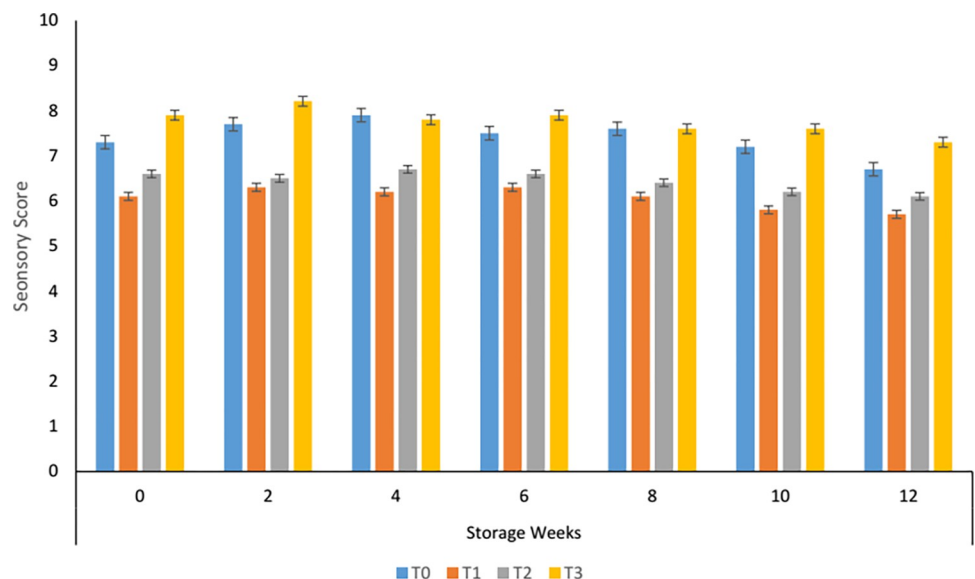


Fig 4. Mouthfeel of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g004>

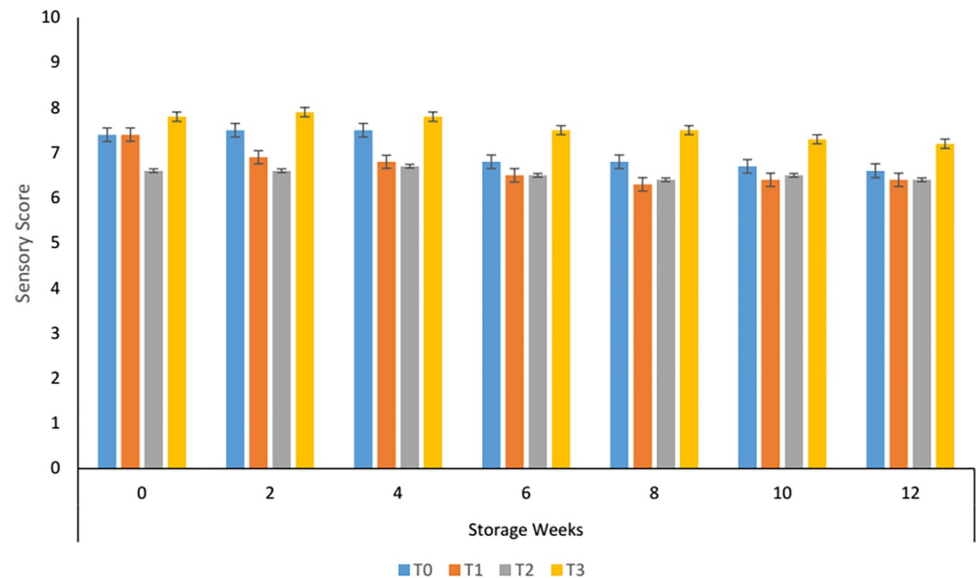


Fig 5. Aroma of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g005>

3.8.5. Effect of storage on the aroma of carrot supplemented tomato sauce. Aroma is one of the sensory attributes directly perceived by the consumer. During the study period, the effect of different treatments and storage conditions on the sensory attributes of carrot sauce was significant (Fig 5). The highest aroma score was observed in the sample having 70% of carrot paste when compared with control and remained in the acceptable range till the end of the storage period. Throughout the storage T₁ and T₂ not yielded the best. The results of the study were in corroboration the findings of Din *et al.*, [26].

3.8.6. Overall acceptability of carrot supplemented tomato sauce. Data analyzed by the sensory panelist for the overall acceptability of the carrot sauce supported that a highly significant difference was found among the treatments ($P < 0.05$). The effect of storage was less prominent during the whole period (Fig 6). The maximum acceptable range was observed in

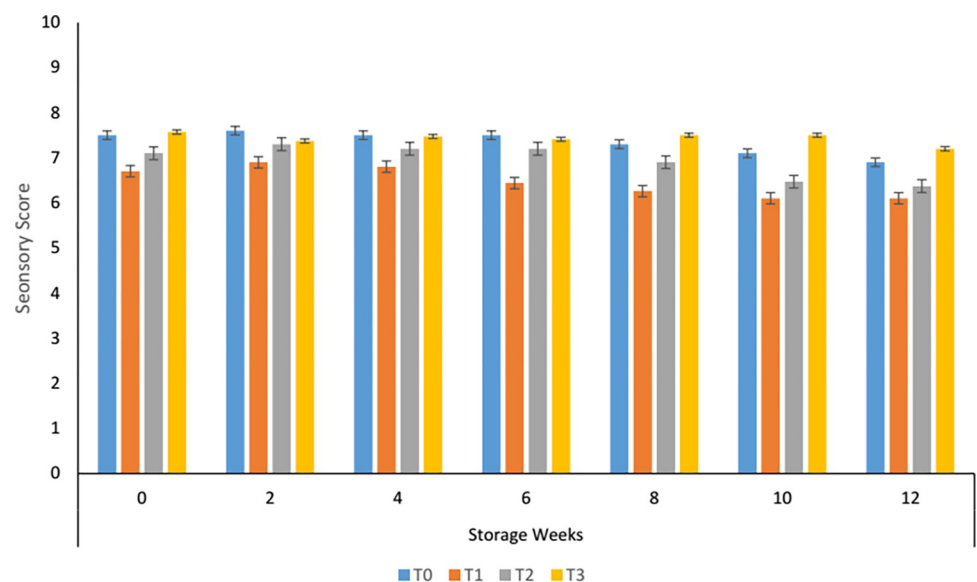


Fig 6. Overall acceptability of carrot sauce.

<https://doi.org/10.1371/journal.pone.0273857.g006>

T₃ and then in the control sample. The overall acceptability of samples having 50 and 60% of carrot paste was not satisfactory at the end of storage. Din *et al.*, [26] reported a similar while storing moringa root supplemented tomato sauce for 90 days with a value of 7.46. A similar reducing trend in the overall acceptability of tomatoes during post-harvest changes was observed by Landy *et al.* [42]. Conclusively, carrot sauce having 70% carrot paste behaved well during the whole storage period with the good sensory and nutritional profile.

4. Conclusion

The study was focused to develop a carrot-based sauce to enhance the β -carotene contents and assess the changes in the composition of the sauce. As sauces are mostly utilized with fried products to enhance flavor and taste. The product was stored for 12 weeks and evaluated at 15 days intervals to check the effect of storage on its nutritional composition, shelf stability, and consumer acceptance. The study proved that sauce containing 60% carrot paste showed better sensory and textural attributes as compared to control. The deteriorative changes in T₂ were also lesser as compared to other treatments. It was concluded that carrot supplemented tomato sauce can be used as a functional food for the betterment and treatment for the vit-A deficient population.

Supporting information

S1 Data. Raw results carrot sauce.
(XLSX)

Author Contributions

Conceptualization: Muhammad Sameem Javed.

Data curation: Adnan Amjad, Muhammad Jawad.

Formal analysis: Faiz-ul-Hassan Shah, Muhammad Abrar.

Investigation: Zulfiqar Ahmad.

Methodology: Aneela Hameed.

Software: Muhammad Junaid Anwar.

Visualization: Ammar Ahmad Khan.

Writing – review & editing: Muhammad Amir.

References

1. Leocádio PC, Lopes SC, Dias RP, Alvarez-Leite JI, Guerrant R L, Malva JO, et al. The Transition from Undernutrition to Overnutrition Under Adverse Environments and Poverty: The Risk for Chronic Diseases. *Front. Nutr.* 2021 April 23; 173(8):676044 <https://doi.org/10.3389/fnut.2021.676044> PMID: 33968973
2. Mirza Z. Healthcare and Budget 2021–22. *Dawn News.* 2021 August 6. <https://www.dawn.com/news/1639082>
3. Xu Y, Shan Y, Lin X, Miao Q, Lou L, Wang Y, et al. Global patterns in vision loss burden due to Vitamin A deficiency from 1990 to 2017. *Public Health Nutr.* 2021 March 29; 24(17):5786–94. <https://doi.org/10.1017/S1368980021001324> PMID: 33775269
4. Booth SL, Johns T, Kuhnlein HV. Natural food sources of vitamin A and provitamin A. *Food Nutr Bull.* 1992 March 1; 14(1):1–15.
5. Meléndez-Martínez AJ, Böhm V, Borge GIA, Cano MP, Fikselová M, Gruskiene R, et al. Carotenoids: Considerations for Their Use in Functional Foods, Nutraceuticals, Nutricosmetics, Supplements,

- Botanicals, and Novel Foods in the Context of Sustainability, Circular Economy, and Climate Change. *Annu Rev Food Sci Technol*. 2021 March 25; 12:433–60. <https://doi.org/10.1146/annurev-food-062220-013218> PMID: 33467905
6. Vianny Gutierrez-Cruz. Sauces & Spices (Global Comparison). *Statista*. 2021 October. <https://www.statista.com/outlook/cmo/food/sauces-spices/worldwide#global-comparison>
 7. Nasrollahzadeh M, Nezafat Z, Shafiei N, Soleimani F. Polysaccharides in food industry. In: *Biopolymer-Based Metal Nanoparticle Chemistry for Sustainable Applications*. Iran: Elsevier; 2021. P. 47–96.
 8. Ahmad T, Cawood M, Iqbal Q, Ariño A, Batool A, Tariq RM, et al. Phytochemicals in *Daucus carota* and their health benefits. *Foods*. 2019 Sep 19; 8(9):424.
 9. Derakhshideh M, Rahimi S. Investigation the effects of adding carrot pomace and stevia in the formulation of tomato sauce on its quality. *J. Food Process. Preserv*. 2021 August 23; 13(1):31–44.
 10. Ghosh S, Adak K, Saha P, Upadhyay S, Ghosh A, Das P, et al. Beta-carotene retention as retinol activity equivalent at different cooking and storage variants. *Int. Food Res. J*. 2019 February; 26(1):355–61.
 11. Reboul E. Mechanisms of carotenoid intestinal absorption: Where do we stand?. *Nutrients*. 2019 April 13; 11(4):838. <https://doi.org/10.3390/nu11040838> PMID: 31013870
 12. Mefleh M, Pasqualone A, Caponio F, Faccia M. Legumes as basic ingredient in the production of Dairy-Free Cheese Alternatives: A Review. *J Sci Food Agric*. 2022 Jan 15; 102(1):8–18. <https://doi.org/10.1002/jsfa.11502> PMID: 34453343
 13. Khokhar KM. Production Status of Major Vegetables in Pakistan, Their Problems and Suggestions. *Agric. Corner*. 2014;9. <http://www.agricorner.com/production-status-of-major-vegetables-in-pakistan-their-problems-and-suggestions/#sthash.F271PIH8.dpuf>
 14. Tomas M, Beekwilder J, Hall RD, Sagdic O, Boyacioglu D, Capanoglu E. Industrial processing versus home processing of tomato sauce: Effects on phenolics, flavonoids and in vitro bioaccessibility of antioxidants. *Food chem*. 2017 April 1; 220: 51–58. <https://doi.org/10.1016/j.foodchem.2016.09.201> PMID: 27855932
 15. AOAC. Association of Official Analytical Chemists. *Official Methods of Analysis* 18th Ed. AOAC press Arlington VA-USA. 2012.
 16. Joseph S, Chatli MK, Biswas AK, Sahoo J. Oxidative stability of pork emulsion containing tomato products and pink guava pulp during refrigerated aerobic storage. *J Food Sci Technol*. 2014 November; 51(11):3208–3216. <https://doi.org/10.1007/s13197-012-0820-y> PMID: 26396313
 17. Abbas KA, Abdulkarim SM, Saleh AM, Ebrahimian M. Suitability of viscosity measurement methods for liquid food variety and applicability in food industry-A review. *J Food Agri Environ*. 2010 July 1; 8(3):100–7.
 18. Everitt M. Consumer-targeted sensory quality. In: *Global issues in food science and technology*. United States: Academic Press; 2009.p. 117–128.
 19. Steel RGD, Torrie JH, Dicky DA. *Principles and Procedures of Statistics*. In: *A Biometrical Approach*. 3rd Edition, McGraw Hill, Inc. Book Co., New York, 352–358.
 20. Sanjel S. EFFECTS OF DRYING METHODS (SOLAR AND CABINET) AND PACKAGING MATERIAL (LDPE AND HDPE) ON RETENTION OF β -CAROTENE IN DEHYDRATED CARROT (*Dacus carota*) [dissertation]. Nepal: Department of Food Technology Central Campus of Technology Institute of Science and Technology Tribhuvan University, Nepal; 2019.
 21. Fiedor J, Burda K. Potential role of carotenoids as antioxidants in human health and disease. *Nutrients*. 2014 January 27; 6(2):466–488. <https://doi.org/10.3390/nu6020466> PMID: 24473231
 22. Mehrad B, Ravanfar R, Licker J, Regenstein JM, Abbaspourrad A. Enhancing the physicochemical stability of β -carotene solid lipid nanoparticle (SLNP) using whey protein isolate. *Food Res Int*. 2018 March 1; 105:962–9. <https://doi.org/10.1016/j.foodres.2017.12.036> PMID: 29433295
 23. Li H, Zhang J, Wang Y, Li J, Yang Y, Liu X. The effects of storage conditions on lycopene content and color of tomato hot pot sauce. *Int J anal. Chem*. 2018 January 31;2018. <https://doi.org/10.1155/2018/1273907> PMID: 29619049
 24. Martínez-Hernández GB, Boluda-Aguilar M, Taboada-Rodríguez A, Soto-Jover S, Marín-Iniesta F, López-Gómez A. Processing, packaging, and storage of tomato products: influence on the lycopene content. *Food Eng Rev*. 2016 March; 8(1):52–75.
 25. Liang X, Yan J, Guo S, McClements DJ, Ma C, Liu X, et al. Enhancing lycopene stability and bioaccessibility in homogenized tomato pulp using emulsion design principles. *IFSET*. 2021 January 1; 67:102525.
 26. Din A, Amir RM, Ameer K, Ahmad A, Nadeem M, Chughtai MFJ, et al. Assessment of quality attributes of tomato sauce supplemented with moringa root. *Food Science and Technology*. 2020 May 8; 40:1014–1020.

27. Pourfarzad A, Derakhshan NT. Effect of xanthan, guar and tragacanth on quality and shelf life of hazelnut sauce: study with generalized regression, PCA and PLSR techniques. *J Food Meas Charact*. 2021 December; 15(6):5008–20.
28. Prakash A, Prabhudev SH, Vijayalakshmi MR, Prakash M, Baskaran R. Implication of processing and differential blending on quality characteristics in nutritionally enriched ketchup (Nutri-Ketchup) from acerola and tomato. *J food sci technol*. 2016 August; 53(8):3175–3185. <https://doi.org/10.1007/s13197-016-2291-z> PMID: 27784912
29. Yim DG, Jin SK, Hur SJ. Microbial changes under packaging conditions during transport and comparison between sampling methods of beef. *J Anim Sci Technol*. 2019 January; 61(1):47. <https://doi.org/10.5187/jast.2019.61.1.47> PMID: 31333861
30. Sucharitha KV, Beulah AM, Ravikiran K. Effect of chitosan coating on storage stability of tomatoes (*Lycopersicon esculentum* Mill). *Int Food Res J*. 2018; 25(1): 93–99.
31. Soma PK, Williams PD, Lo YM. Advancements in non-starch polysaccharides research for frozen foods and microencapsulation of probiotics. *Front Chem Eng China*. 2009 December; 3(4):413–426.
32. Kumar V, Kumar L, Kumar K, Goyal SK, Kumar A, Jain G. Physico-chemical and quality evaluation of tomato ketchup during storage. *South Asian J Food Technol Environ*. 2015; 1(3&4):250–255.
33. Ahouagi VB, Mequelino DB, Tavano OL, Garcia JAD, Nachtigall AM, Boas BMV. Physicochemical characteristics, antioxidant activity, and acceptability of strawberry-enriched ketchup sauces. *Food Chem*. 2021 March 15; 340:127925. <https://doi.org/10.1016/j.foodchem.2020.127925> PMID: 32889213
34. Bannwart GCMDC Bolini HMA, Toledo MCDF Kohn, APC Cantanhede GC. Evaluation of Brazilian light ketchups II: quantitative descriptive and physicochemical analysis. *Food Sci Technol*. 2008; 28:107–115.
35. Xu Q, Adyatni I, Reuhs B. Effect of processing methods on the quality of tomato products. *Food Nutr Sci*. 2018 February 7; 9(2):86–98.
36. Diantom A, Curti E, Carini E, Vittadini E. Effect of added ingredients on water status and physico-chemical properties of tomato sauce. *Food chem*. 2017 December 1; 236:101–108. <https://doi.org/10.1016/j.foodchem.2017.01.160> PMID: 28624078
37. Kaur R, Kaur K, Ahluwalia P. Effect of drying temperatures and storage on chemical and bioactive attributes of dried tomato and sweet pepper. *LWT*: 2020 January 1; 117:108604.
38. Szczesniak AS. Effect of storage on texture. *Food storage stability*. 1998;191–244.
39. Kamsina K, Anova IT. Storage resistance and a level of panelist acceptance on tomatoes sauce enriched with kandis acid (*Garcinia cowa* Roxb) extract as a preservative. In: The 4th International Conference on Mathematics, Science, Education and Technology (ICOMSET) in Conjunction with the 2nd International Conference on Biology, Science and Education (IcoBioSE); 2020 July 23–24; Padang, Indonesia: Conference series. *J Phys*. 2021; 1940(1):012086.
40. Nkhata SG, Ayua EO. Quality attributes of homemade tomato sauce stored at different temperatures. *Afr J Food Sci*. 2018 May 31; 12(5):97–103.
41. Xu S, Sun X, Lu H, Yang H, Ruan Q, Huang H, et al. Detecting and monitoring the flavor of tomato (*Solanum lycopersicum*) under the impact of postharvest handlings by physicochemical parameters and electronic nose. *Sensors*. 2018 June 6; 18(6):1847. <https://doi.org/10.3390/s18061847> PMID: 29882769
42. Landy P, Boucon C, Kooyman GM, Musters PA, Rosing EA, De Joode T, et al. Sensory and chemical changes in tomato sauces during storage. *J Agric food chem*. 2002 May 22; 50(11):3262–3271. <https://doi.org/10.1021/jf011249i> PMID: 12009996