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EXPLORING THE PHYSICOCHEMICAL, NUTRITIONAL, ANTIOXIDANT AND STORAGE STABILITY OF DEHYDRATED TOMATOES AND ITS UTILIZATION FOR THE DEVELOPMENT OF PIZZA SAUCE

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Abstract
This study was conducted to develop and analyze a pizza sauce made using dehydrated tomato powder in an attempt to determine how three varying mixtures (T_0-T_3) of dehydrated tomato powder would affect its physicochemical, phytochemical, microbiological and sensory properties. Standard analytical methods and statistical analysis were used to determine the analytical parameters of color parameters, pH, titratable acidity, total soluble solids (TSS), and bioactive compounds, load of the microbes and consumer acceptability of the prepared pizza sauces. Phytochemical evaluation indicated a tremendous increase in bioactive constituents in increasing levels of treatment. Analysis of color showed that the L, a, and b values have been increasing and that treatment T_3 gives the highest values (L = 48.15, a = 41.39, b* = 48.86*), thus revealing an improvement in the visual quality. The amounts of total phenolic content and total flavonoid content increased (150.24 mg GAE/100 g (T_0) to 270.26 mg GAE/100 g (T_3) to 99.80 mg QE/100 g to 122.07 mg QE/100 g of both at T_3. The antioxidant activity also increased with DPPH radical scavenging activity increasing to 87.33% with the maximum of 395.60 to T_3 of ABTS Microbial analysis indicated a highly significant reduction in microbial load across treatments, with the lowest count observed in T_3 (1.78±0.08 log CFU/g) compared to the control (2.78±0.05 log CFU/g), demonstrating improved microbial stability.*

1. INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) are one of the pillars of world food systems, as they are versatile in kitchen uses, and they have a nutritional profile. In this introduction, the physicochemical and storage stability of dehydrated tomatoes is discussed and its applications are developed with respect to Pizza Sauce. The post-harvest losses are relieved, nutrients like vitamins are conserved and shelf life is extended using dehydration methods which permit year-long availability and use in

processed foods such as Sauces. Next sections explore the background, nutritional significance, issues, dehydration measures and factors that affect their quality of tomatoes (Singh *et al.*, 2025). Tomatoes are among the most popular horticultural crops in the world as the yearly production of the crop exceeds 180 million tons of tomatoes, which are used in fresh and processed products such as tomato Sauces and tomato juices (Furuta *et al.*, 2025). Tomatoes are also known to have a powerful nutritional composition, as it is one of the primary sources of antioxidants, vitamins, and minerals that provide a wide range of health promotion (Haraira *et al.*, 2022).The color red, known as lycopene, has anticancer effects, which have been shown to reduce the risks of prostate, lung, stomach, breast and colorectal cancers and has antioxidant, antiangiogenic and anti-inflammatory effects. It also helps to keep the heart healthy, reduce hypertension, atherosclerosis, LDL cholesterol and platelet aggregation (Collins *et al.*, 2022). Tomatoes are also known to have a powerful nutritional composition, as it is one of the primary sources of antioxidants, vitamins, and minerals that provide a wide range of health promotion (Haraira *et al.*, 2022). They also have vital bioactive substances, including lycopene (more than 80 percent of carotenoids), 7-10 percent 2-carotene, vitamins A, C and E, flavonoids, phenolic compounds and minerals including Mn, Fe, Cu, Zn, K and Ca (Haraira *et al.*, 2022). The color red, known as lycopene, has anticancer effects, which have been shown to reduce the risks of prostate, lung, stomach, breast and colorectal cancers and has antioxidant, antiangiogenic and anti-inflammatory effects. It also helps to keep the heart healthy, reduce hypertension, atherosclerosis, LDL cholesterol and platelet aggregation (Collins *et al.*, 2022). The high nutrient content of tomatoes as value-added products due to the abundance of vitamins and antioxidants can be improved by processing methods to produce products with longer shelf life such as Sauces and powders (Haraira *et al.*, 2022). The business of tomato-based Sauces, which is one of the most popular in the global food industry, is a day-to-day food that underlines the growth of the market due to its versatility in the ready-to-eat-meal industry and convenience products. They are produced through high levels of processing to ensure consistency in flavor, and their production is part of a multi-billion-dollar industry that is supported by urbanization and the hectic lifestyles. The role in international trade is increased by innovation in formulation, including reduced-sugar ones, as they are oriented at the health trends (Mercier *et al.*, 2023).

2. MATERIALS AND METHODS

The research was carried out in the postgraduate laboratories of the Faculty of Science and Technology at UCP. It will specify the materials, tools and procedures used, including the experimental design, data collection methods, and analytical techniques. This paper aims at examining the physicochemical and storage stability of dehydrated tomatoes and their use in preparing pizza sauce. The study will improve stability and bioavailability of these nutrients on storage without compromising the product sensory features and physicochemical properties.

2.1. Procurement of raw material

The local market was used to get fresh and ripe tomato fruit. The tomato pulp was later separated into powder to be included in a pizza sauce composition.

2.1.1. Preparation of tomato powder by hot air oven drying

To begin with, the tomatoes were picked and cleaned to take away dust, dirt and other impurities. They were cut into thin pieces and left in a solution of citric acid solution after 30 minutes. The tomatoes were treated then rinsed with distilled water and put under a fan to drain out the surplus water. Then, they were put in the trays and dried in the hot air oven at 50°C during 24 hours. They were cooled down and ground to fine powder using a grinder. The end product had the same texture, appearance, quality, taste and color and was of good quality. To begin with, the tomatoes were picked and cleaned to take away dust, dirt and other impurities. They were cut into

thin pieces and left in a solution of citric acid solution after 30 minutes. The tomatoes were treated then rinsed with distilled water and put under a fan to drain out the surplus water. Then, they were put in the trays and dried in the hot air oven at 50°C during 24 hours. They were cooled down and ground to fine powder using a grinder. The end product had the same texture, appearance, quality, taste and color and was of good quality.

2.2. Shelf-life Analysis of tomato powder

The powder was tested for shelf stability over three months. Variations of each prepared powder were stored in airtight containers at room temperature and periodically examined to assess their shelf life. During storage, the containers were visually inspected for color changes or microbial spoilage. Every 15 days, one sample from each variation was also evaluated for its sensory properties.

2.3. Proximate Analysis

Tomato powder was further analyzed by proximate analysis, in which the amounts of protein, moisture, fat, and fiber were determined using AOAC (2023). Each sample was replicated three times for the specified procedure.

2.4 Physicochemical Analysis

2.4.1. Color

Color was measured for the value-added pasta with a colorimeter. The L, a*, and b* three- color values were recorded. Each value was an average of three measurements taken at different tomato powder positions. Theoretically, a color might range from 100- pure white- to almost 0 and black. Lightness in the color lightness means the higher the L value. Nevertheless, it is worth pointing out that while the a* and b* values correspondingly represent (+) redness/ (−) greenness and (+) ye lowness/ (−) blueness.

2.4.2. Titratable acidity (TA)

The titratable acidity of the fortified ketchup was determined using a standard titration method as given in (AOAC, 2023) official method (No.942.15). A 10 mL sample of each ketchup was diluted with 90 mL of distilled water and titrated with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as the indicator. The titration was stopped when the mixture reached a faint pink endpoint, and the volume of NaOH used was recorded (Tomovska, Gjorgievski and Makarijoski, 2016). Values for titratable acidity were noted in triplicate by using the formula as given below;

$$\text{Titratable Acidity (\%)} = \frac{\text{Vol. of NaOH solution used} \times 0.060 \times \text{Normality of NaOH}}{\text{Weight of sample(g)}} \times \frac{}{100}$$

Where;
V = Volume of NaOH used (in mL),
N = Normality of NaOH (0.1 N),
0.060 = Equivalent weight of acetic acid
W = Weight of the ketchup sample (in grams)

2.4.3. pH

The pH of the tomato samples was measured according to the official (AOAC 2016) method (No. 942.15). Specifically, a 50 mL sample was placed in a 100 mL beaker, and the pH was determined by using a digital pH meter (Ino Lab pH 720, Germany). pH values were recorded in triplicate.

2.4.4. Total soluble solids (TSS)

The total soluble solids (TSS) of the tomato samples were measured using a digital refractometer (Model: HI96800, Hanna, made in Romania), following the official Method No. 920.151 of (AOAC, 2016). Approximately 2-3 drops of the fruit sample were placed on the refractometer prism, and the TSS value was measured in triplicate. The results for total soluble solids are given in °Brix.

2.4.5. Microbiological Analysis

The sample of tomato powder was gathered aseptically in sterile containers to avoid the contamination. Every sample was appropriately labeled with appropriate data such as the collection date, time and place. A sterile blender was used to homogenize the materials as needed. Liquid samples were completely mixed prior to analysis, whereas solid samples were diluted in clean buffered peptone water to a specified weight.

Produced the countable colony ranges serial dilutions were carried out by first transferring 1 ml of the sample into 9 ml of sterile diluent, and then performing consecutive dilutions. Plates were incubated for 48 hours at 35-37°C. In the end, after incubation colonies were recorded.

2.5. Pizza Sauce Development

Pizza Sauce was made by blending tomato puree with dried tomato powder to boost solids, flavor, and thickness. The tomato puree was gently heated to 70-75 °C, then dried tomato powder was rehydrated in warm water and stirred in slowly to ensure even mixing. Vegetable or olive oil was added to improve mouth feel and flavor extraction, followed by sugar and salt to balance the tomatoes' natural acidity. Fresh ginger and dried herbs like oregano and basil were included to develop the signature aroma and flavor. To produce a stable, non-separating Sauce with ideal viscosity, stabilizers such as xanthan gum or carrageenan were gradually added to the hot mixture while stirring vigorously. The mixture was simmered for 10–15 minutes until thick and spreadable, then cooled quickly and stored in the refrigerator until ready to use.

Table 1. Treatment plan for the development of Pizza Sauce

Treatment	Tomato puree (%)	Dehydrated Tomato Powder (%)
T0	100	0
T1	90	10
T2	80	20
T3	70	30

2.6. Proximate Analysis

Tomato powder was further analyzed by proximate analysis, in which the amounts of protein, moisture, fat, and fiber were determined using AOAC (2023). Each sample was replicated three times for the specified procedure.

2.6.1. Moisture contents

The moisture content of tomato powder was analyzed by the oven drying method. The sample material, two to five grams, was filled into a thoroughly weighed, dry, and clean crucible. The crucible with the sample was weighed. The sample was maintained at 105°C in a hot air oven for four to six hours until its weight was constant, meaning all the moisture had been evaporated. To prevent it from picking up moisture from the air, the sample was dried, cooled in a desiccator, and subsequently weighed. The formula below was used to calculate the moisture content.

$$\text{Moisture (\%)} = \frac{\text{Fresh sample (g)Dried sample weight (g)}}{\text{Fresh sample weight}} \times 100$$

2.6.2. Crude ash contents

Gooch crucibles were prepared for the ash content process by cleaning and drying. In crucibles that had been previously weighed, a sample of 5 g of dry material devoid of fat was burned over low heat. For 5 to 6 hours, these scorched samples were kept at a temperature between 500 and 600 °C in a muffle furnace (Hassan *et al.*, 2024). Following the production of greyish-to-white ash, crucibles were removed from the muffle furnace, allowed to cool in the desiccator, and weighed to perform further calculations using the formula.

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

2.6.3. Crude protein contents

Firstly, 5 g of the dried material was weighed and placed in a Kjeldahl flask. 5g of material should be mixed with 10 mL of concentrated H_2SO_4.Initially heated slowly before raising the temperature. Boiled for 2-4 hr, or until the solution turned clear. The digested solution was cooled. To dilute the digested solution, 50ml of distilled water were added. Made the solution alkaline, gradually added the 50 mL of 40%

NaOH. Heat and the distillation unit were connected to the flask. Meanwhile, the ammonia gas that was emitted was absorbed into a flask that contained methyl red and 50 ml of a 4% boric acid solution. The production of ammonium borate caused the boric acid to become sea green colored. The ammonium borate solution should be titrated with 0.1 N HCl / H_2SO_4 until it attained the end point, which was pink color and noted the amount of acid that was used. The quantity of nitrogen in the sample was estimated, and the nitrogen percentage was multiplied by the conversion factor to produce the crude protein level. To get reliable findings, proper titration, thorough digestion, and reagent handling were guaranteed.

$$\text{Nitrogen (\%)} = \frac{\text{Volume of 0.1N suphuric acid used} \times 0.0014 \times 250}{\text{Sample weight} \times \text{Aliquot volume}} \times 100$$

Crude protein = Nitrogen (%) ×5.80

2.6.4. Crude fat contents

Soxhlet apparatus was used to estimate the percentage of total fat. This was followed by weighing a 250 mL dry volumetric flask which was then filled with n- hexane (extraction solvent). The paper thimble was prepared by putting a 10 g dry, moisture-free sample in a filter paper and rolling it into the jacket of the sample. Once the apparatus was fitted, the solvent was given time to condense and evaporate, which finished thirty-nine extraction cycles. It was carried out again and the change of the extract color to clear liquid carefully observed.

$$\text{Crude fat (\%)} = \frac{\text{Weight of hexane extract (g)}}{\text{Sample weight (g)}} \times 100$$

2.6.5. Crude fiber contents

Crude fibers were calculated using samples that were fat-free. Five grams of the material were placed in a dry, clean beaker with 200 mm of a 1.25% H2SO4 solution content (Mishra *et al.*, 2024). After the procedure, the mixture was heated in 100 0 C during 30 minutes using a hot plate. The subsequent filtration of the resultant solution was done after the material had cooled to ambient temperature and this was achieved with a series of washings.

$$\text{Crude Fiber \%} = \frac{\text{Weight after Drying} - \text{Weight after ashing}}{\text{Sample weight(g)}} \times 100$$

2.6.6. NFE contents

The nitrogen-free extract (NFE) is a way to estimate the carbohydrate content of food products. It is calculated by subtracting the sum of other known components (fiber, protein, fat, moisture, and ash) from the total weight of the sample.

NFE%= 100- (Crude fat%+ Crude protein%+ Crude fiber%+ Moisture% + Ash %)

2.7. Physicochemical Analysis

2.7.1. Color

Color was measured for the value-added pasta with a colorimeter. The L, a*, and b* three- color values were recorded. Each value was the average of three measurements taken at different positions on the Pizza Sauce. Theoretically, a color might range from 100- pure white- to almost 0 and black. Lightness in the color lightness means the higher the L value. Nevertheless, it is worth pointing out that while the a* and b* values correspondingly represent (+) redness/ (−) greenness and (+) ye lowness/(−) blueness (Uribe-Wandurraga *et al.*, 2021).

2.7.2. Titratable acidity (TA)

The titratable acidity of the Pizza Sauce was determined using a standard titration method as specified in the AOAC (2023) official method (No. 942.15). A 10 mL sample of each ketchup was diluted with 90 mL of distilled water and titrated with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as the indicator. The titration was stopped when the mixture reached a faint pink endpoint, and the volume of NaOH used was recorded. Values for titratable acidity were noted in triplicate by using the formula as given below (Tomovska, Gjorgievski and Makarijoski, 2016).

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2.7.3. pH

The pH of the Pizza Sauce samples was measured according to the official (AOAC 2016) method (No. 942.15). Specifically, a 50 mL sample was placed in a 100 mL beaker, and the pH was determined by using a digital pH meter (Ino Lab pH 720, Germany). pH values were recorded in triplicate (Uribe-Wandurraga *et al.*, 2021).

2.7.4. Total soluble solids (TSS)

The total soluble solids (TSS) of the Pizza Sauce samples were measured using a digital refractometer (Model: HI96800, Hanna, made in Romania), following the official Method No. 920.151 of (AOAC, 2016). Approximately 2-3 drops of the fruit sample were placed on the refractometer prism and the TSS value was measured in triplicate. The results for total soluble solids are given in °Brix.

2.7.5. Microbiological Analysis

The sample of Pizza Sauce was gathered aseptically in sterile containers to avoid contamination. Every sample was appropriately labelled with appropriate data such as the collection date, time and place. A sterile blender was used to homogenize the materials as needed. Liquid samples were completely mixed prior to analysis, whereas solid samples were diluted in clean buffered peptone water to a specified weight. Produced the countable colony ranges serial dilutions were carried out by first transferring 1 ml of the sample into 9 ml of sterile diluent, and then performing consecutive dilutions. Plates were incubated for 48 hours at 35-37°C. In the end, after incubation colonies were recorded (Amin *et al.*, 2018).

2.8. Phytochemical Analysis

Total phenolic content and DPPH were analyzed in the following phytochemical analysis.

2.8.1. Extract preparation

The sample is dried in a hot air oven at 45°C for one to two hr. To the sample of 5 g, 10 mL of distilled water and 40 mL of methanol were added, and the mixture was shaken for an hour at 40°C before filtering through Whatman filter number 40 to extract the free chemicals. Further, the filtrate was centrifuged at room temperature for 15 min at 4000 rpm. The supernatant was stored in the dark at 20°C until further use for the determination of TPC and DPPH scavenging activity. The extraction was performed in triplicate sample (de Vasconcellos Santos Batista *et al.*, 2020).

2.8.2. Total Phenolic Content (TPC)

The TPC was assessed by calorimetric analysis. 500 µL of distilled water and 125 µL of the lyophilized sample were added into a test tube. Thereafter, 125 µL of Folin-Ciocalteu reagent was added and allowed to settle for six min. After this, 1.25 mL of 7% Na2CO3 was added. The final volume was obtained with distilled water, to be 3 ml. The solution was again incubated for ninety minutes at room temperature in a dark environment. The absorbance of the solution was measured using a double beam spectrophotometer set at 760 nm. For a blank, purified water was used, meaning no extraction was made. The unit of TPC was mg GAE/100g dry stuff. Three separates analyses of the standard and the sample were performed. Means ± standard deviation was computed and displayed with the average value (Zhang, Peng, Li, & Tian, 2023).

$$C = {C * V}/{m}$$

Where,
M=Weight of the extract
C=Gallic acid concentration derived from calibration curve in mg/ml. c= TPC expressed in mg GRE/g of extract.

2.8.3. DPPH Activity

Functional biscuits samples were tested for antioxidant activity and their ability to scavenge the free radical DPPH (2, 2-diphenyl-2-picrylhydrazyl). By adding 80% ethanol, the supernatant layer (0.1 mL) was diluted with 0.5

mL. Additionally, a vortex mixer was used to mix in 0.5 mL of DPPH. For fifteen minutes, the finished solution was left at room temperature in the dark. The spectrophotometer 752D was used to measure the absorbance of the pasta sample at 517 nm. Scavenging activity was computed using the provided formula (Khan *et al.,* 2019).

$$\text{Scavenging activity} = 1 - \frac{Af}{Ao} X\ 100$$

The absorbance values of the sample and blank are denoted by A_o and A_f, respectively

2.8.3. Total Flavonoid Contents

A colorimetric test was used to measure the concentration of each flavonoid. First, 0.5 mL of the sample was mixed with 2 mL of distilled water, and then 0.15 mL of $NaNO_2$ solution was added. The solution was mixed in a vortex for three minutes. Following the incubation period, 0.15 mL of a 10% $AlCl_3$ solution was added to the mixture, and it was let stand for five to six minutes. After adding 1 mL of NaOH to the resultant solution, methanol was added right away to bring the amount up to 5 mL. After thoroughly mixing the solution, it was let stand for another forty minutes. After the pink mixture was obtained, absorbance at 510 nm was compared with a blank. Rutin equivalents, in which RE represents milligrams of rutin equivalent, were utilized to express TFC per gram of dry extract. Rutin was used as the reference point. The TFC of cupcakes was determined using a rutin calibration curve (5-10 micrograms per milliliter (µg/mL)), and the results were then expressed as mg RU (rutin equivalents) per gram (mg/g) of sample (Chen & Tengku, 2020).

2.8.4 ABTS

The antioxidant property of the samples of the pizza sauce was measured using the ABTS radical cation decolorization assay according to the originally developed protocol. To find the solution with ABTS, 7 mM ABTS was reacted with 2.45 mM potassium persulfate to produce an ABTS, which was kept in the dark at ambient temperature to get full radical development of 12-16 hours. Before the analytical measurement, the ABTS 734nm solution was centrifuged using deionized water or phosphate buffer until the solution attained an absorbance of 0.70±0.02] at 734nm as measured on UV-VIS spectrophotometer. A 1ml aliquot of the respective sample extract was then mixed with the diluted ABTS aliquot of the ABTS solution and left to incubate in the dark over a period of 6min. The subsequent reduction in absorbance at the 734 nm was noted, and the antioxidant activity was measured which was percent of the ABTS radical activity (Muzolf-Panek and Stuper-Szablewska, 2021).

The percentage inhibition of ABTS radicals was calculated using the following formula:

$$\textbf{ABTS Radical Scavenging activity} = 1 - \frac{AO - A1}{Ao} X\ 100$$

2.9. Microbiological Analysis

The sample of Pizza Sauce was gathered aseptically in sterile containers to avoid contamination. Every sample was appropriately labelled with appropriate data such as the collection date, time and place. A sterile blender was used to homogenize the materials as needed. Liquid samples were completely mixed prior to analysis, whereas solid samples were diluted in clean buffered peptone water to a specified weight. Produced the countable colony ranges serial dilutions were carried out by first transferring 1 ml of the sample into 9 ml of sterile diluent, and then performing consecutive dilutions. Plates were incubated for 48 hours at 35-37°C. In the end, after incubation colonies were recorded (Amin *et al.* 2018).

2.10. Statistical Analysis

The statistical analysis was performed on the obtained data to determine the level of significance. Three experimental replicates were done in each treatment and the standard deviation was calculated by summing up the means. To clarify the presence of statistically significant observed differences, analysis of variance (ANOVA) software was used (Montgomery *et al.*, 2017).

3. RESULTS

3.1 Physicochemical Analysis of Tomato powder

3.1.1 pH

The storage time of the two drying methods showed a significant decrease in PH as the storage time went up. The mean PH in table 2 as shown below was reduced at day 0 was 5.05±1.03 and day 90 was 4.67±0.05, which demonstrates that acidification occurred with the course of the storage. This reduction could be caused by chemical change, breakdown of carbohydrates and the accretion of organic acids over the years.

Table 2: Means for the pH of powder

Treatments	Storage days				Means
	0	30	60	90	
SD	4.52±0.06^{e}	4.44±0.05^{f}	4.35±0.02^{g}	4.27±0.05^{h}	4.40±0.04^{b}
HD	5.58±0.04^{a}	5.45±0.06^{b}	5.23±0.05^{c}	5.06±0.03^{d}	5.33±0.03^{a}
Means	5.05±0.03^{a}	4.95±0.04^{b}	4.79±0.02^{c}	4.67±0.05^{d}	

3.1.2 Lightness (L)

This reduced weight of HD powder can be attributed to even distribution of heat and reduced time of drying which suppresses non-enzymatic browning. On the other hand, SD powder has low values of L, which might be due to long exposure to sunlight and oxygen, which enhances the process of pigment degradation and browning. A significant reduction in L values with an increase in the storage time in both drying methods was a gradual and notable reduction. The average L was decreased by 31.74 ± 0.03 (not of day 0) to 26.27 ± 0.05 (not of day 90) which shows that the tomato powder became darkened but very slowly during storage. Maillard reactions, pigment oxidation and changes in color during storage due to the presence of moisture may be responsible of this reduction in lightness.

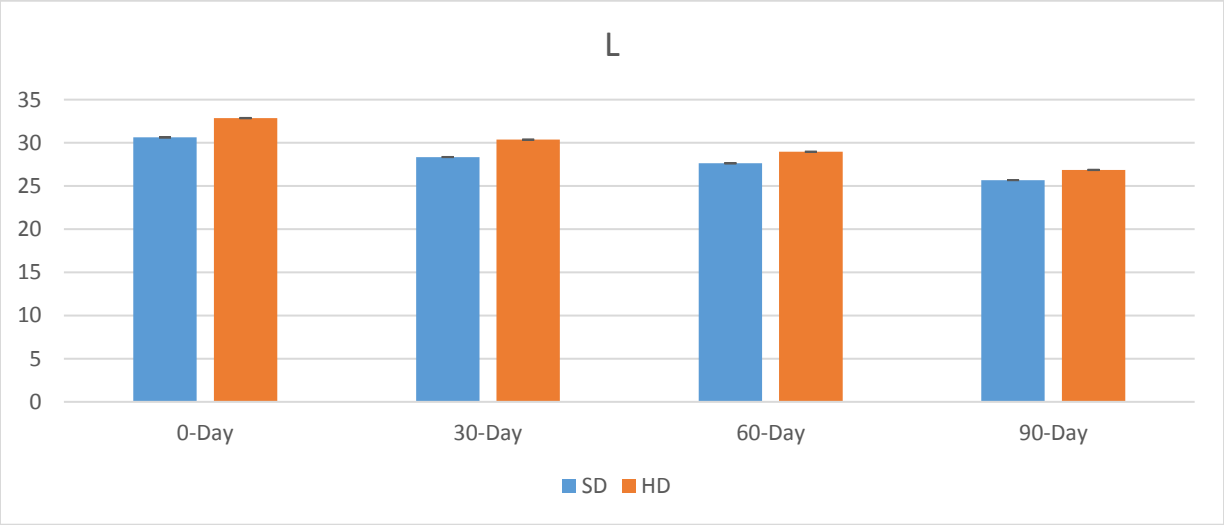


Figure 1. Graphical Representation of L of tomato powder

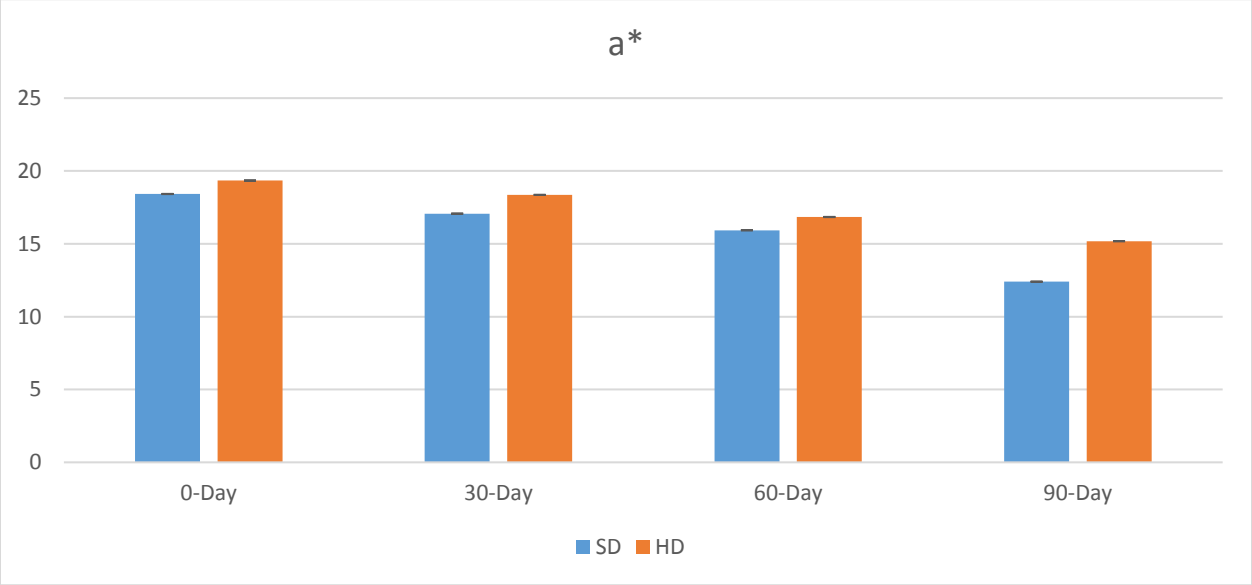


Figure 2. Graphical Representation of a* of tomato powder

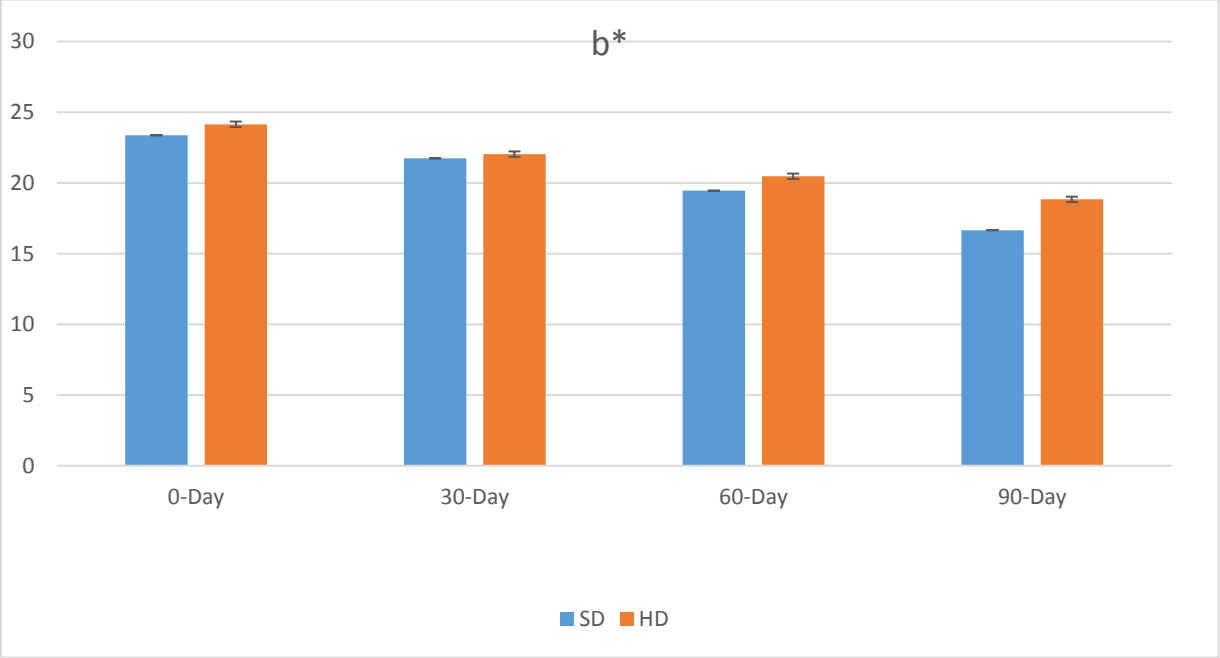


Figure 3. Graphical Representation of b* of tomato powder

3.2 Microbial Analysis

This implies that the drying method (sun drying and hot air oven drying) as well as the storage time were a significant factor in the growth of microbes in storage. On day 0 tomato powder dried with hot air oven (HD) had highly lower microbial counts (2.360.4 log CFU/g) than the sun-dried (SD) powder (3.950.6 log CFU/g). The lower microbial count of HD powder can be explained by influence of controlled drying temperature, quicker moisture elimination and lower contamination of the environment, and higher documented counts of SD powder could be attributed to longer drying period and exposure to

the open environment. There was a large increment in microbial activity with longer storage time in both drying processes. The mean CFU of microbes was 3.15 log at day 0 and 6.54 logs at day 90, further showing that there was an increase in mean CFU of microbes throughout the storage. This growth could be due to the presence of moisture, nutrients and good storage conditions that allow present growth of microbes with time.

Table 3: Analysis of Mean for the Microbial Activity of powder

Treatments	Storage days				Means
	0	30	60	90	
SD	3.95±0.06^{e}	5.08±0.05^{d}	6.91±0.02^{b}	7.06±0.05^{a}	5.75±0.04^{a}
HD	2.36±0.04^{f}	3.94±0.06^{e}	5.07±0.05^{d}	6.03±0.03^{c}	4.35±0.03^{b}
Means	3.15±0.03^{d}	4.51±0.04^{c}	5.99±0.02^{b}	6.54±0.05^{a}	

3.3. Physicochemical analyses of Pizza Sauce

3.3.1 Color Analysis of Pizza Sauce

Table 3.2 shows marked improvement in the mean values. Values were the lowest in control T_0 (L = 37.24, a* = 23.17, b* = 34.86). These parameters were increased with every new treatment with a significant variation. The outcome of treatment T_3 gave the lightest sauce (L = 48.15) and the most intense red hue (a* = 41.39), as well as the yellowness (b* = 48.86). To conclude, modifications in treatments, leading to T_3, produced a much lighter and colored Pizza Sauce with a richer color in comparison with control.

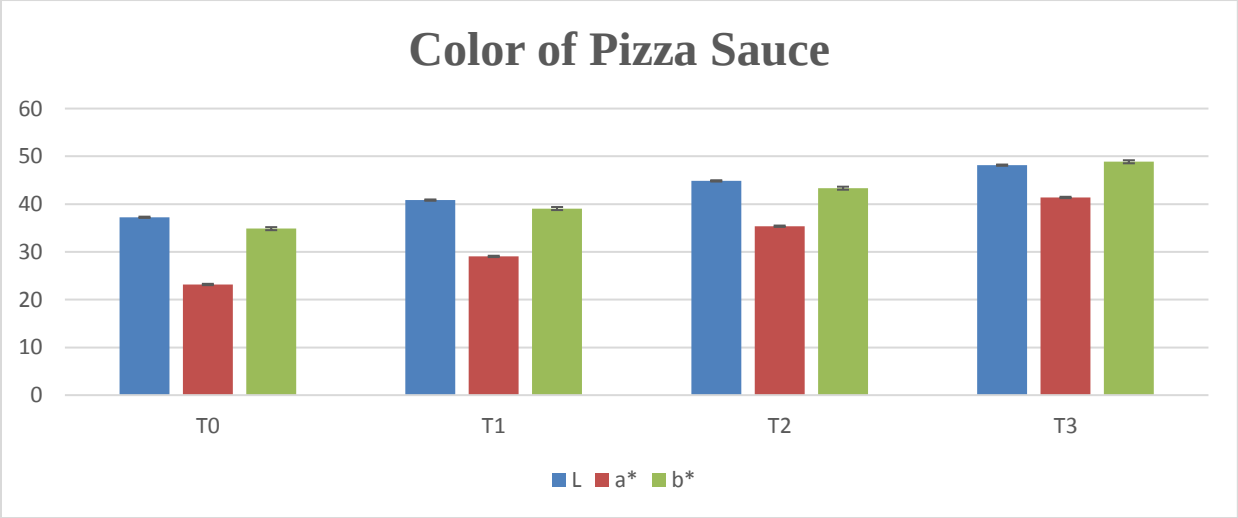


Figure 4. Graphical Representation of the Color of Pizza Sauce

3.4. Analysis of pH, Acidity and TSS of Pizza Sauce

The results show that changes in the formulation have resulted in large changes in the basic chemical makeup of the sauce and its concentration.

These particular changes are depicted in the mean values of Table and provide clear and consistent distributions of the various levels of treatment. There was a good relationship between acidity and pH, and their correlations were negative. The lowest pH (4.22) and the highest acidity (0.37 0.37) was measured with the control treatment (T0). The pH came to a peak with every consecutive treatment (T1 to T3), but acidity reached its lowest value in T3 (0.06%). At the same time, the soluble solids (TSS) content also grew continuously (T0 7.75) up to T3 (8.84 3). To summarize, the implemented treatments essentially and substantially altered the properties of the sauce, yielding the product, which was less acidic, had a higher pH, and had higher concentration. The treatment T3 gave the most distinct profile with the highest pH, lowest acidity and high TSS content

Table 5. Means table for pH, Acidity, and TSS of Pizza Sauce

Treatments	pH (%)	Acidity (%)	TSS (%)
T_0	4.22 ± 0.02^{bc}	0.37 ± 0.01^{a}	7.75 ± 0.02^{d}
T_1	4.36 ± 0.05^{ab}	0.23 ± 0.03^{b}	8.16 ± 0.05^{c}
T_2	4.48 ± 0.03^{a}	0.13 ± 0.04^{bc}	8.58 ± 0.03^{b}
T_3	4.57 ± 0.06^{c}	0.06 ± 0.08^{c}	8.84 ± 0.04^{a}

3.5. Phytochemicals Analysis of Pizza Sauce

3.5.1 Analysis for TPC, TFC, DPPH, ABTS Pizza Sauce

Mean values show a positive trend that is evident with regards to treatments. TPC (150.24 mg) per 100 g), TFC (99.80 mg per 100 g), and DPPH inhibition (66.90 %), and ABTS activity (328.91 umol TE /100 g) were always lower in the control sauce (T0). A significant increase in most of the parameters was seen in each of the levels of successive treatments.

The highest concentrations and activities were generated by treatment T3: TPC (270.26 cristallina GAE 100 g), TFC (122.07 criinqlu QE 100 g), DPPH radical -scavenging action (87.33 per cent), ABTS radical -cation scavenging action (395.60 umol TE 100 g). It is important to mention that the shift of TPC between T1 and T2 was significantly steep. However, the general trend between T0 and T3 is a positive one, whereas the ABTS at T2 (362.33 µmol TE/100 g) was smaller than at T1 (381.33 µmol TE/100 g), which may be an indication of a non-linear or compound-specific reaction to this mechanism of antioxidant action.

Table 6. Mean Table for TPC, TFC, DPPH, ABTS of Pizza Sauce

Treatments	TPC	TFC	DPPH	ABTS
T_0	150.24 ± 0.10^{d}	99.80 ± 0.02^{d}	66.90 ± 0.08^{d}	328.91^{d}
T_1	165.45 ± 0.60^{c}	105.67 ± 0.03^{c}	76.79 ± 0.09^{c}	381.33^{b}

T_2	250.17±0.50^b	108.61±0.53^b	80.77±0.10^b	362.33^c
T_3	270.26±0.40^a	122.07±0.08^a	87.33±0.30^a	395.60^a

3.6. Antimicrobial Analysis of Pizza Sauce

The mean microbial counts (Table 3.6) reveal a clear treatment-related trend. The control Sauce (T0) exhibited the highest microbial activity. A significant reduction was achieved with all modified treatments. While the decrease from T0 to T3 is not perfectly linear across every intermediate step, Treatment T3 resulted in the lowest and statistically most distinct microbial count, demonstrating its superior efficacy in suppressing microbial growth compared to both the control and other treatment levels.

Table 7. Mean table for Microbial Activity of Pizza Sauce

Treatment	Means
T_o	2.78±0.05^d
T_1	2.17±0.05^b
T_2	2.47±0.08^c
T_3	1.78±0.08^a

3.7. Sensory Evaluation of Pizza Sauce

On the whole, the experience with the sensory evaluation shows that formulation plays an important role in influencing the sensory quality of pizza sauce. Of all the treatments T_2 was the most favored formulation because it scored highest in all the sensory attributes. These results endorse the existence of an ideal level of ingredient inclusion to boost the sensory pleasure but too much inclusion can eliminate consumer acceptability.

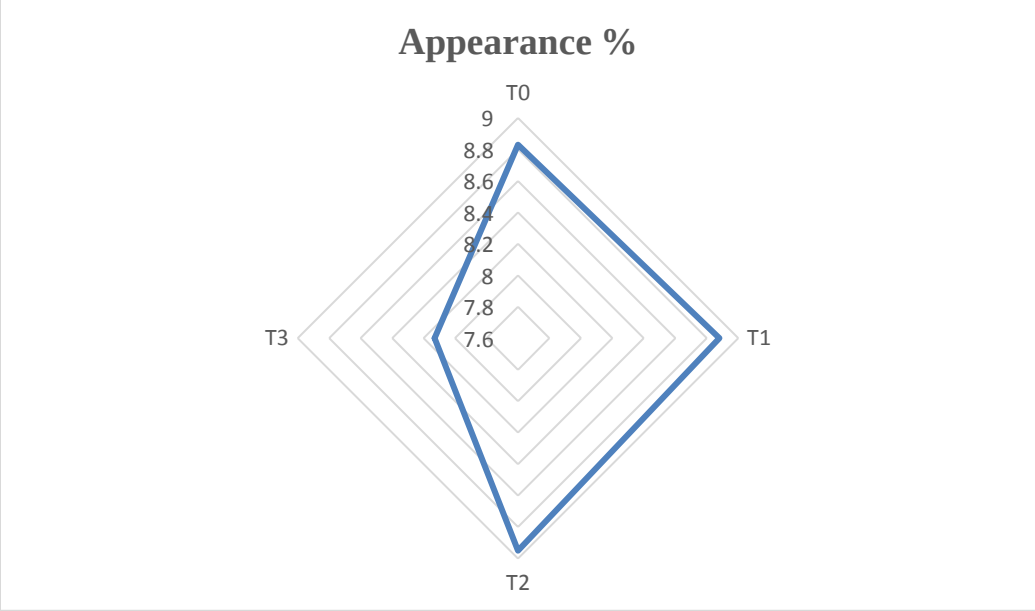


Figure 5. Graphical Representation of Appearance of Pizza Sauce

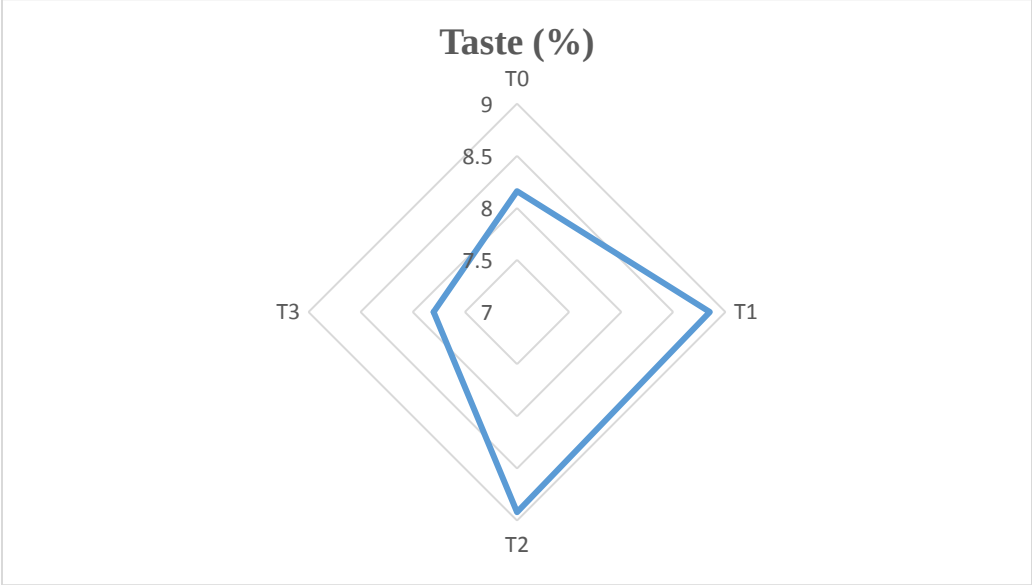


Figure 6. Graphical Representation of Taste of Pizza Sauce

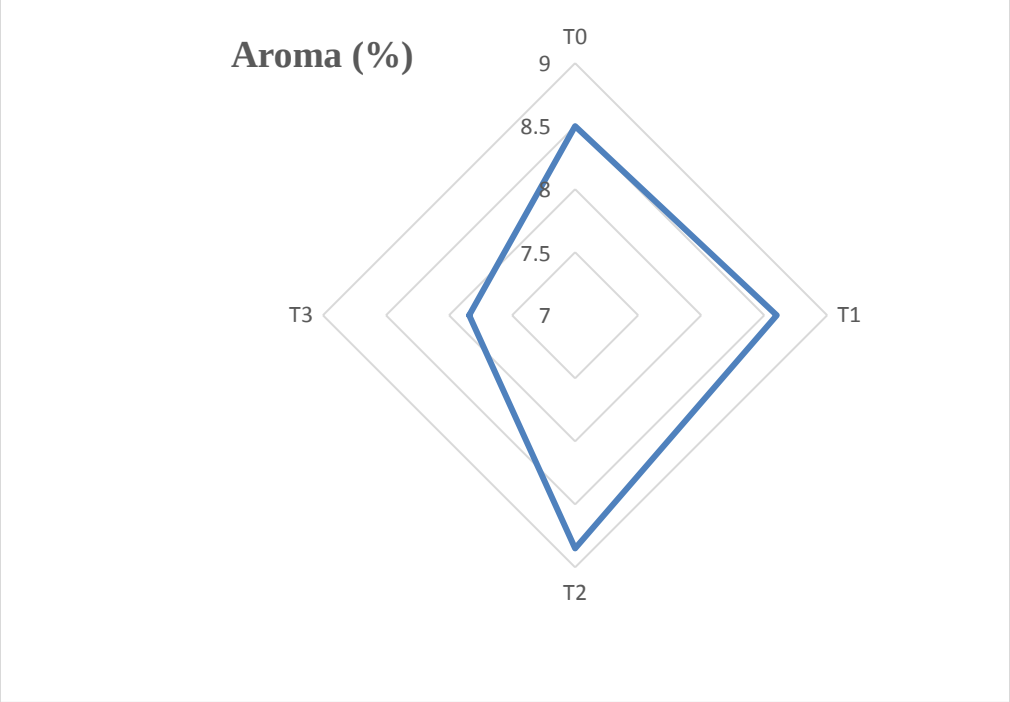


Figure 7. Graphical Representation of Aroma of Pizza Sauce

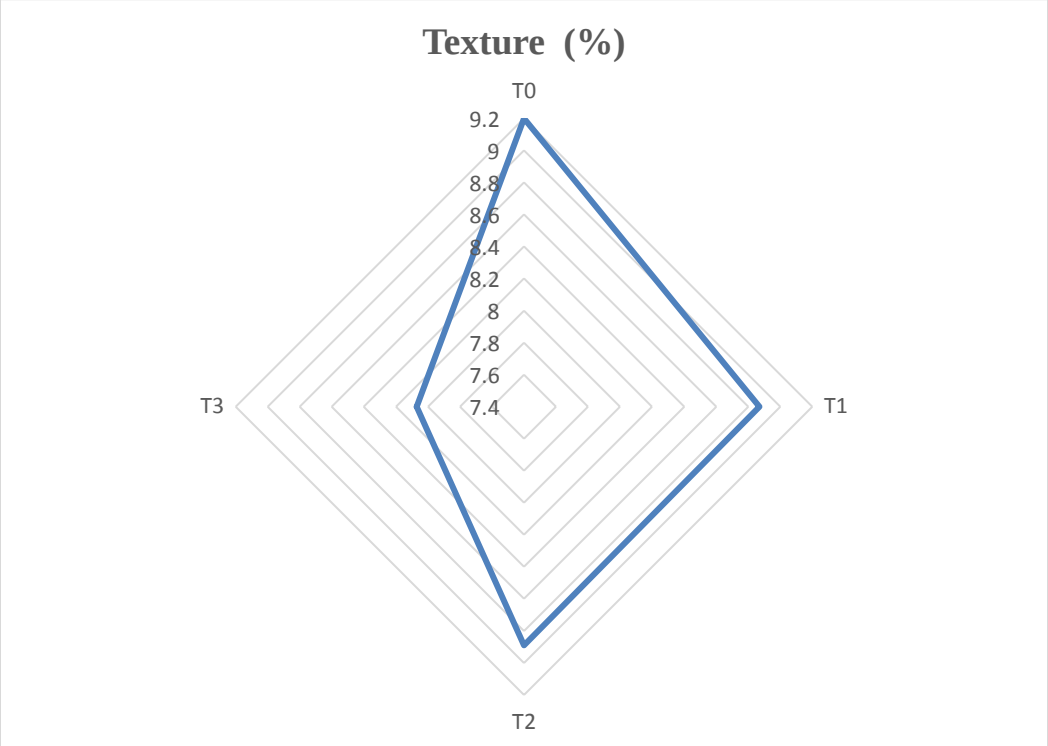


Figure 8. Graphical Representation of Texture of Pizza Sauce

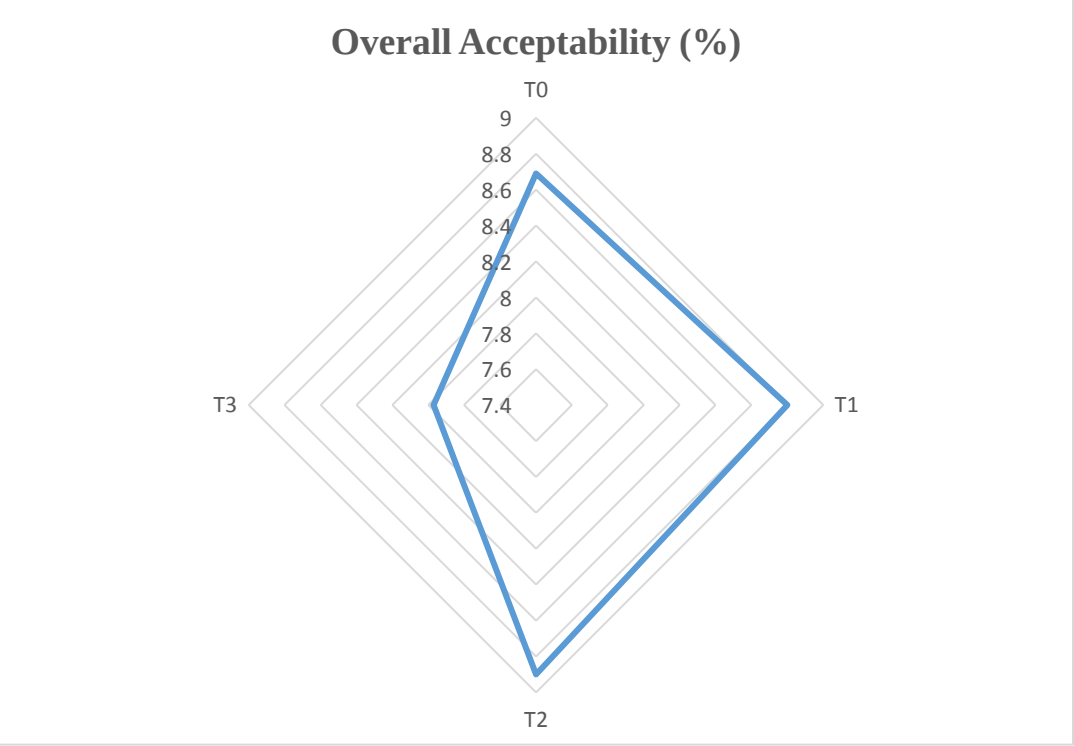


Figure 9. Overall acceptability of tomato sauce

4. DISCUSSIONS

The chapter presents the research results regarding the manufacturing, quality attributes, storage stability, and usage of tomato powder prepared by using sun drying (SD) and the hot-air oven drying (HD) methods and its introduction into the Pizza Sauce formulations. The findings are discussed under the study objectives and in relation with the literature available, which brings into light their implications on formulation of functional foodstuffs, shelf-life, and value-added use of tomatoes. The constraints of the study and future research direction are also discussed.

The drying method and storage time had a significant effect on the pH of tomato powder, and their interaction on the pH ($P<0.05$). It was observed that HD powder was always at higher pH when compared to SD powder at any period of storage. The pH of HD powder was 5.58±0.04 SD powder had a pH of 4.52±0.06. At 90 days' storage, the pH ranged at 5.06 GB SD, with a difference of 0.03 and 4.27, with a difference of 0.05, respectively (Kumar *et al.,* 2020).

After 90 days' storage, the pH value was 5.06 SD GD, with a range of 0.03, and 4.27, with a range of 0.05 respectively (Kumar *et al.,* 2020Z). The increased pH of HD powder might be due to drying under control, which minimized acid decomposition but SD powder exposed to long-time sun might have interacted with the acid and oxidized it more quickly. These results are consistent with those of (Guemouni *et al.,* 2023), who have found higher retention of pH in oven dried tomato powders.

The decrease in acidity was also found to be significant on the storage SD powder ($P < 0.01$) decreased from 0.67±0.04% at day 0 to 0.36±0.03% at day 90, while HD powder decreased from 0.73±0.06% to 0.53±0.05%. The general mean pH decreased by 6.5 percent 0.70 deliberately 0.03 to 0.45 deliberately 0.05, which indicates the gradual degradation of organic acids. HD powder was more acidic, which indicated the capability of withstanding drying to retain the organic acids (Sarkar *et al.,* 2025). Similarly, there was a good relationship between acidity and pH, and their correlations were negative in pizza sauce analysis. The lowest pH (4.22) and the highest acidity (0.37 0.37) was measured with the control treatment (T0). The pH came to a peak with every consecutive treatment (T1 to T3), but acidity reached its lowest value in T3 (0.06%). At the same time, the soluble solids (TSS) content also grew continuously (T0 7.75) up to T3 (8.84) which aligns with results of (Yegrem *et al.,* 2022) where T3 in pizza sauce was (8.7) So, the implemented treatments essentially and substantially altered the properties of the sauce, yielding the product, which was less acidic, had a higher pH, and had higher concentration. The treatment T3 gave the most distinct profile with the highest pH, lowest acidity and high TSS content

Lightness (L therein referred to as L-) of tomato powder reduced immensely after storing. Firstly, HD powder was lighter (32.86 takes suitable value) than SD powder (30.63 takes some suitable value). Redness (a*) diminished from 19.34 ± 0.04 (HD) and 18.42 ± 0.06 (SD) to 15.18 ± 0.03 (HD) and 12.40±0.05 (SD). Yellowness (b*) also declined from 24.15±0.04 (HD) and 23.37±0.06 (SD) to 18.84 ± 0.03 (HD) and 16.66 ± 0.05 (SD) over the 90 days. These losses depict oxidative destruction of carotenoids and especially in the sun-dried powder. This can be explained by the aggressive drying of HD powder since the cells were exposed to a shorter drying duration and an even distribution of heat, as (Yegrem *et al.,* 2022) study corroborates. Table 3.2 of pizza sauce showed marked improvement in the mean values. Values were the lowest in control T_0 ($L = 37.24$, $a^* = 23.17$, $b^* = 34.86$). These parameters were increased with every new treatment with a significant variation. The outcome of treatment T_3 gave the lightest sauce ($L = 48.15$) and the most intense red hue ($a^* = 41.39$), as well as the yellowness ($b^* = 48.86$). Modifications in treatments, leading to T_3, produced a much lighter and colored Pizza Sauce with a richer color in comparison with control (Sarkar *et al.,* 2025).

Both drying methods saw the increase of microbial counts in storage but HD powder showed lower counts. At day 0, SD powder had 3.95 ± 0.06 log CFU/g, and HD powder had 2.36 ± 0.04 log CFU/g. By day 90, counts rose to 7.06 ± 0.05 log

CFU/g (SD) and 6.03 ± 0.03 log CFU/g (HD).At day 90, the counts had increased up to 7.06 6.03 respectively (SD)logs CFU g and HD. There was a big effect on interaction between drying approach and storage ($P < 0.01$), which showed that neither of them exerted a significant effect on microbial proliferation. HD powder is associated with low amounts of lower microbial growth that can be explained by rapid dehydration and low degree of contamination in the course of drying, which aligns with the results of (Engin *et al.*, 2023). On the whole, the experience with the sensory evaluation shows that formulation plays an important role in influencing the sensory quality of pizza sauce. Of all the treatments T_2 was the most favored formulation because it scored highest in all the sensory attributes. These results endorse the existence of an ideal level of ingredient inclusion to boost the sensory pleasure but too much inclusion can eliminate consumer acceptability which aligns with results of (Sarkar *et al.*, 2025).

5. CONCLUSION

Overall, the findings of the research determine that Pizza Sauce can be effectively prepared using tomato powder, and hot air drying has become the most appropriate technique of developing high-quality products with shelf stability. The findings clearly depict that tomato powder is a suitable raw material when preparing Pizza Sauce with benefits in form of long shelf life, ease of storing and all-year-round availability. Of the two methods of drying that were tested, hot air drying was found to be best in terms of maintaining the quality characteristics of the tomato powder and the product Pizza Sauce than sun drying. The advantage of using tomato powder is that it reduces post-harvest losses as well as provides a convenient substitute of fresh tomatoes at a reasonable cost to the economy as well as a sustainable substitute in preparing Sauce. This study highlights the possibilities of tomato powder to commercial Pizza Sauce production and justifies its use in food processing industry. Future research can focus on how to streamline the packaging system, incorporate natural preservatives, and determine nutritional and antioxidant modification in the course of prolonged storage to continue to provide better quality products in the market.

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