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The Influence of pH, Acidity, and Sugar Content on the Taste and Quality of Tomato Paste

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تأثير الرقم الهيدروجيني والحموضة ومحتوى السكر على طعم وجودة معجون الطماطم

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Abstract:
This study reviewed some of the chemical and physical properties of twenty tomato paste samples, measuring pH, total titratable acidity, and sugar content as quality and safety criteria. Twenty commercial samples were analyzed using standard methods, including titration, a pH meter, and high-performance liquid chromatography (HPLC). Most samples yielded results within the permissible limits of pH ≤ 4.6, with the exception of three samples that exceeded this limit, increasing the potential for the growth of some microbes, such as Clostridium botulinum. The total acidity resulting from titration ranged between 32,698 and 44,810 mg/kg, which remains below the maximum permissible limit of 7% (70,000 mg/kg). The sugar content showed significant variation, with 15 samples exceeding the permissible limit of 12 mg/kg, indicating the potential for sugar addition during manufacturing and processing.
The study emphasizes the need for strict regulation and monitoring of pH, sugar content, and the use of advanced analytical methods, such as Fourier transform infrared spectroscopy (FT-IR), to enhance quality control and consumer protection.

Keywords: Tomato paste, pH, acidity, sugars, food safety, quality control.

الملخص
استعرضت هذه الدراسة بعض الخصائص الكيميائية والفيزيائية لعشرين عينة من معجون الطماطم، مع قياس الرقم الهيدروجينيpH والحموضة الكلية القابلة للمعايرة، ومحتوى السكر كمعايير للجودة والسلامة. حُللت عشرون عينة تجارية باستخدام طرق قياسية، شملت المعايرة، وجهاز قياس الرقم الهيدروجيني، وكروماتوغرافيا السوائل عالية الأداء HPLC أظهرت معظم العينات نتائج ضمن الحدود المسموح بها للرقم الهيدروجيني pH ≤ 4.6، باستثناء ثلاث عينات تجاوزت هذا الحد، مما زاد من احتمالية نمو بعض الميكروبات، مثل بكتيريا كلوستريديوم البوتولينوم. تراوحت الحموضة الكلية الناتجة عن المعايرة بين 32,698 و44,810 ملغم/كغم، وهي نسبة أقل من الحد الأقصى المسموح به وهو 7% (70,000 ملغم/كغم). أظهر محتوى السكر تباينًا كبيرًا، حيث تجاوزت 15 عينة الحد المسموح به وهو 12 ملغم/كغم، مما يشير إلى احتمالية إضافة السكر أثناء التصنيع والمعالجة. وتؤكد الدراسة على ضرورة التنظيم الصارم ومراقبة درجة الحموضة ومحتوى السكر واستخدام أساليب تحليلية متقدمة مثل مطيافية الأشعة تحت الحمراء لتحويل فورييه (FT-IR)لتعزيز مراقبة الجودة وحماية المستهلك.

الكلمات المفتاحية: معجون طماطم، رقم الهيدروجيني، الحموضة، السكريات، سلامة الغذاء، ضبط الجودة.

I-Introduction

The sensory and nutritional qualities of fruit-based products are predominantly shaped by their chemical composition, with acidity and sugar content serving as critical components. These factors work together to form the flavor profile of fruits, influencing consumer preferences and guiding decisions in industrial production. Among fruit-derived products, tomatoes stand out due to their distinctive combination of organic acids, natural sugars, and amino acids. This blend not only defines their taste but also impacts their shelf life and nutritional value. Understanding parameters such as pH levels, titratable acidity, and sugar composition is essential for ensuring food quality and safety while optimizing processing methods. Furthermore, health concerns related to excessive sugar consumption or sustained exposure to certain acid levels highlight the need for meticulous monitoring of these factors. The interplay of sweetness and acidity significantly contributes to the overall flavor of fruits and tomato-based products, commonly measured through the sugar-to-acid ratio. Sweetness is assessed using a refractometer to determine soluble solids percentage, whereas acidity is analyzed by titrating juice with a standardized sodium hydroxide solution (0.1 N NaOH). This ratio serves as a crucial quality marker in industrial settings, where maintaining the ideal balance boosts consumer appeal[2]..

Organic acids, such as citric and malic acids, are fundamental to the acidity in fruits. Acidity is evaluated using the pH scale, which ranges from 0 (highly acidic) to 14 (strongly alkaline), with a neutral midpoint at 7. Lower pH values indicate greater acidity, often linked to antimicrobial properties due to the presence of these acids. As vital metabolic intermediates, organic acids also contribute to the signature sourness of fresh fruits. Tomatoes are classified as moderately acidic fruits, with pH levels typically falling between 4.2 and 4.9. Citric acid constitutes the majority of their organic acid content, making up about 41.07% to 67.41% of total acidity, while malic acid accounts for 11.67% to 20.97%. During ripening, the concentration of these acids declines naturally, leading to an increase in pH and a reduction in titratable acidity. This transformation affects both flavor and storage characteristics of tomato-based products. For processed items like tomato paste, an average pH of around 4.6 is common. Keeping the pH below this critical value is essential for microbial safety during thermal processing; if it rises above 4.6, acidifying agents like citric acid or lemon juice can be added to restore it to safe levels. Sugars, particularly glucose and fructose, play an equally important role in defining tomato quality by contributing to their sweetness and overall taste profile. In fully ripe tomatoes, soluble solids content—which includes sugars—typically ranges from 4% to 7%. The delicate balance between sugar and acid is key for flavor; tomatoes with more sugar and less acid tend to taste blandly sweet, whereas those with higher acid and lower sugar levels are perceived as sharply acidic. This sugar-to-acid ratio significantly shapes the sensory appeal of tomatoes, influencing the interplay between sweetness and sourness that drives consumer preferences. Effective management of this ratio is a central focus for breeding efforts aimed at producing tomato varieties with desirable flavor profiles. [8].

-Literature Review

estimated studied quality standards in 34 types of tomato paste, including acidity, dissolved solids and viscosity consumed in California using microwave, showed improved accuracy results in the three parameters, especially viscosity, and it was concluded that microwave waves gave an accurate estimate of the solid content and viscosity[9]

Another study studied Tomato samples of six different local and international brands were purchased from various retail outlets and analyzed for pH values and microbiological quality. The pH values of all the tomato paste samples analyzed were lower than the critical level of 4.6, with Mamie (a local brand) having the highest pH value of 4.15.[10]

Furthermore A analysis was conducted (pH, TDS and total acidity) by group of researches by heating tomato paste samples and adding stearic acid and storing, The results showed a decrease in pH, TDS and an i69) ncrease in total acidity with storage time.[11]

conducted a study of the effect of starch (potato, rice starch, yam starch and corn starch) on the physical ,chemical and sensory properties of tomato paste with some preservatives, samples were stored for three months, The results showed an increase in TDS and acidity during storage while pH decreased and they found that starches had an effect on moisture content during the storage period and it became clear that samples containing potato and corn starch retained their properties after 3 months.[12]

1843 samples of tomato paste were supplied in four different leading tomato processors in California, USA. The reference levels of quality traits including, glucose, fructose, and citric acid were determined by official methods. A high correlation between the reference values and portable Fourier transform infrared spectroscopy FT-IR spectrometer predicted values was observed from partial least square regression PLSR models. The standard errors of prediction were low.[13]

The sugars (glucose, fructos and total reducing sugars) were determined in a fast and robust way in California for 120 samples of tomato paste using a portable mid-infrared spectrometer combined with multivariate analysis device as well as an HPLC device to determine the reference levels of reducing sugars and reference values and low standard errors It was found that use of infrared rays can give accurate results, less time and less cost due to the lock of reagents.[14]

also Studied Some physical and chemical properties of different types of tomato paste consumed in Nigerian market, including protein ,sugars, TDS and acidity. were studied . The results showed that they contain high ratios of acidity and sugars higher than the values recommended by the Codex Alimentarius Commission (CAC) containing less than recommended percentages of TDS, for identification of tomatoes.[15]

II.Materials and methods

High-Performance Liquid Chromatography (HPLC), occasionally referred to as High-Pressure Liquid Chromatography, stands as a sophisticated technique in the realm of column chromatography. It's a vital tool in biochemistry, analytical chemistry, and the pharmaceutical sciences, wielding its power to separate, identify, and quantify active compounds with remarkable precision. Central to this method is the interplay between two distinct phases: the stationary phase, typically represented by a column packed with solid material, and the mobile phase, which is characterized by. propelled through this column under considerable pressure. The magic happens as a detector captures the retention times of various analytes—those times fluctuate based on how each analyte interacts physiochemically with the stationary phase and the makeup of the mobile phase. When it's time to analyze, a minuscule volume of the sample is introduced into the relentless flow of the mobile phase. Separation unfolds as analytes stand apart from one another, distinguished by their varying affinities for the two phases—stationary and mobileThe time it takes for an analyte to exit the column is known as its retention time. The mobile phases often consist of water combined with organic solvents such as methanol or acetonitrile, forming consistent mixtures that enhance the separation process. To tackle complex mixtures more effectively, gradient elution comes into play—a technique that involves a gradual shift in the composition of the mobile phase throughout the run. This dynamic approach enhances resolution, accommodating analytes that possess divergent affinities to the ever-evolving mobile phase, thereby illuminating the path to clearer, more accurate results[16].

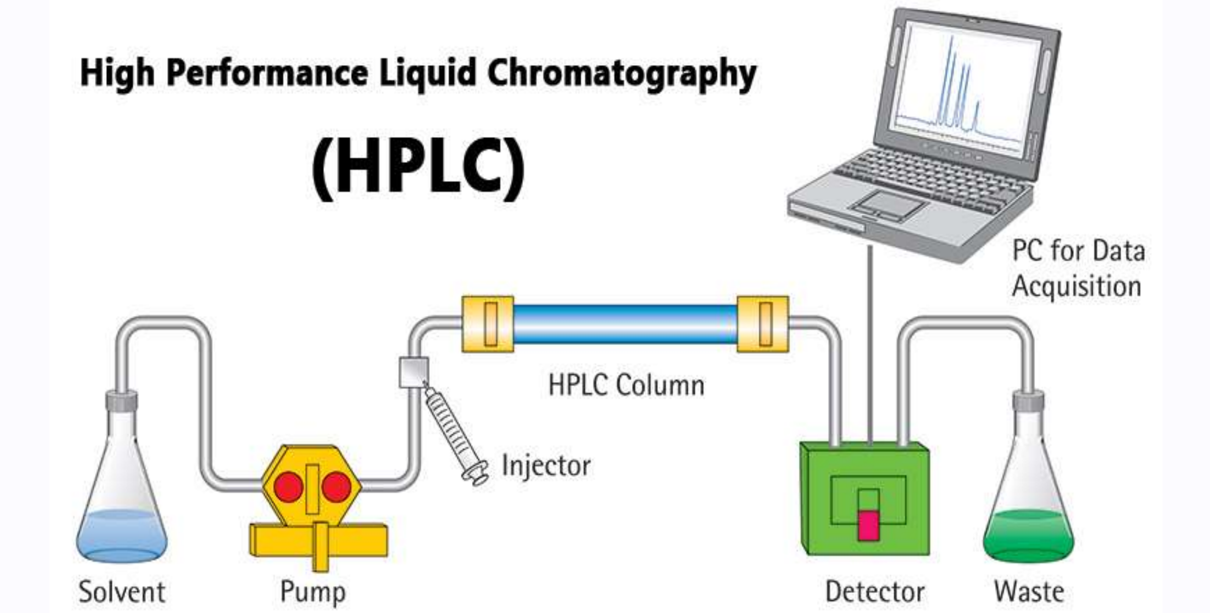

Figure 1. High-performance liquid chromatography components.

Sample preparation and analysis

pH analysis

The pH was assessed using a pH meter, specifically the BOECO PH/ORP/TEMP bench top model BT-700, which hails from the USA. This nifty device features an LCD display, complete with a backlight to make pH, ORP, and temperature readings easy to view. To begin, 5.0 grams of the sample were carefully weighed and placed into a beaker. Following that, 50 cm^3 of distilled water was poured in, and the mixture was shaken well. Calibration of the pH was accomplished using buffer solutions with pH values of 4 and 7, and then readings were recorded [17].

B,2.Acidity analysis

Moving on to the acidity analysis, a 15.0-gram portion of tomato paste found its way into a 100 ml measuring flask, where it was then diluted exactly to the volumetric mark. After filtering the sample, 4 ml of the clear filtrate was transferred into a conical flask. To this, a couple of drops of Phenolphthalein were added, and the mixture was titrated with 0.1 N NaOH until a delightful pink hue appeared [18].

$$\text{Acidity\%} = \text{Consumer Volume} * 0.064 * N * \frac{100}{\text{Sample weight}}$$

Where:
0.064=citric acid partial weight
N=sodium hydroxide standard

Determination of sucrose/D-Glucose/D-fructose

The concentration of Sucrose, D-glucose and D-Fructose in tomato paste was measured by using HPLC ((Agielnt, USA), equipped with a Binary HPLC pump with an injector, a refractive index detector (RI, 2410), and a software monitor with Breeze program. The column used was LC-NH_2 (SUPELCOILTM LC- NH_2, 250 × 4.6 mm, 5 µm, Supelco), was used with an acetonitrile-water mobile phase.

In the primary hydrolysis step, 3.75 mL of 72% aqueous H_2SO_4 was added to the sample (1 mg) in a vial, followed by stirring at room temperature for 2 h. For the second hydrolysis step, 5 mL of H_2O was added and the mixture was heated in an oven at 80 C for 1h.The hydrolysis solution was cooled down in an ice bath and stored at 4 Cº overnight. The hydrolysis solution was neutralized with solid Na_2CO_3 until bubble generation due to CO_2 evolution subsided. The solution was filtered (0.45 ml, 13 mm diameter) and concentrated using lyophilisation . For HPLC Analysis resuspended the hydrolysate in 100 ul D.w.[19]

Calculation

Area% $=\frac{A1(\,standard)}{A2(sample)}=\frac{C1(sample)}{C2(standard)}$

Table(1): Shows the Names of samples and country of origin.

Sample No	The Brand	Origin
1	Sahibaljabal	Tunisia
2	Alburj	Tunisia
3	Albustan	European union
4	Albasmuh	Tunisia
5	Aljayid	Italia
6	Marihan	Italia
7	Aljbal	Italia
8	Famylya	Italia
9	Jouri	Italia
v10	PEETI	Italia
11	Bakina	Cyprus
12	Albarka	Italia
13	Almarwa	Italia
14	ALsafwa	Libya
15	NOVA	Italia
16	Fatura	Italia
17	Alreayhan	Italia
18	Alzayan	European union
19	Alamir	Italia
20	Hikayat	Italia

III. **Results and Discussion**

1. pH Measurements

The pH values of the analyzed tomato paste samples are presented in Table (2) and illustrated in Figure (2). The recorded pH values ranged from 3.56 ± 0.02 to 5.10 ± 0.03, with relative standard deviation (RSD) values ranging from 0% to 2.08%. The highest pH value (5.10) was observed in sample No. 11, while the lowest value (3.56) corresponded to sample No. 1. Except for samples No. 5 (5.07), No. 7 (5.01), and No. 11 (5.10), all samples remained within the recommended range of pH ≤ 4.6, as outlined by Libyan and international standards (WHO, 2020). These findings suggest that some samples, especially sample No. 11, exceeded safe pH levels, which may compromise microbial stability. In particular, Clostridium botulinum, an anaerobic spore-forming bacterium, can grow at pH values above 4.6 and is associated with life-threatening foodborne illnesses[20]

Table (2): pH values of tomato samples.

Sample No.	Mean± STDE	RSD=(STDEV/Mean)*100 %	Sample No.	Mean± STDE	RSD=(STDEV/Mean) *100%
1	3.56±0.02	0.56	11	5.10±0.03	0.58
2	4.99±0.10	2.08	12	4.99±0.03	0.60
3	4.84±0.00	0.00	13	4.95±0.00	0.0
4	5.07±0.00	0.00	14	4.93±0.01	0.20
5	5.00±0.00	0.00	15	4.90±0.01	0.20
6	4.91±0.06	1.22	16	4.87±0.01	0.20
7	5.01±0.01	0.19	17	4.88±0.01	0.20
8	4.92±0.03	0.60	18	5.02±0.01	0.19
9	4.87±0.01	0.20	19	4.95±0.01	0.20
10	4.96±0.02	0.40	20	4.96±0.04	0.80

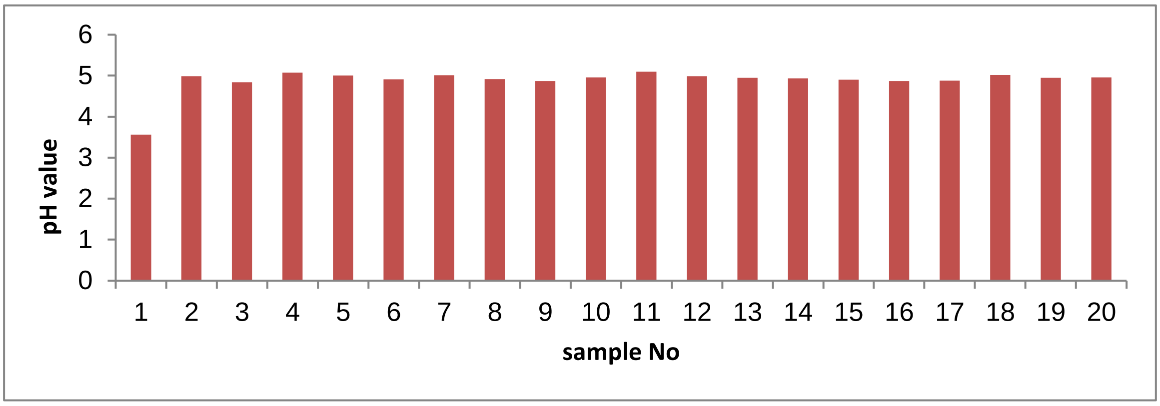

Figure (2): pH value of studied samples.

3.2. Acidity Measurements

As presented in Table (3) and Figer from3), the titratable acidity of the tomato paste samples ranged from 32,698.2 ± 191.7 mg/kg to 44,810 ± 1,046.15 mg/kg, with RSD values between 0% and 3.5%. Sample No. 1 had the highest acid concentration, while the lowest value was detected in sample No. 18. These values were generally lower than those reported by Esra et al. (2020) and remain within the maximum allowable limit of 7% acidity, as specified by Libyan food standards (LBC, 2021). The consistent acidity levels may contribute to product stability, as organic acids such as citric acid and malic acid are often added during processing to enhance flavor and inhibit microbial growth(21).

Table (3): acidity values of tomato samples.

Sample No.	Mean± STDE%	RSD%	Sample No.	Mean± STDE%	RSD%
1	0.17±0.00	0.00	11	0.13±0.00	0.00
2	0.15±0.00	0.00	12	0.14±0.00	0.00
3	0.14±0.00	0.00	13	0.15±0.00	0.00
4	0.16±0.00	0.00	14	0.15±0.00	0.00
5	0.14±0.00	0.00	15	0.15±0.00	0.00
6	0.14±0.00	0.00	16	0.14±0.00	0.00
7	0.14±0.00	0.00	17	0.15±0.00	0.00
8	0.15±0.00	0.00	18	0.16±0.00	0.00
9	0.16±0.00	0.00	19	0.13±0.00	0.00
10	0.15±0.00	0.00	20	0.14±0.00	0.00

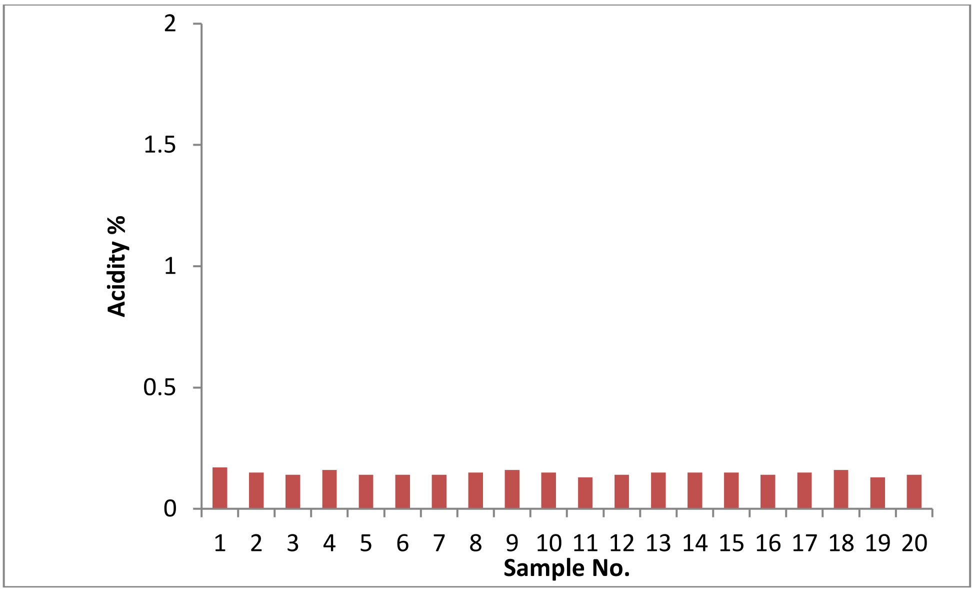

Figure (3): acidty value of studied samples.

3.3. Sugar Concentrations

The sugars' values in tomato paste samples were presented in Table (4) and Figure (4). The values of sucrose range between 12.5 ± 0.1 - 0.56 ± 0.89 mg/kg, and RSD was 0.08 - 4.21 %. Glucose values range between 1.11 ± 0.06 - 10.43 ± 0.15 mg/kg, and RSD was 0.60-5.08 %, while the value of fructose ranges between 0.00 ± 0.00 - 7.6± 0.26 mg/kg and RSD was 0.0 - 0.26 %. The values of total sugar ranged between 5.46 ± 0.01 - 26.93 ± 0.01 mg/kg and RSD 0.00 - 4.97 %; the highest values for sucrose, glucose, and total were for sample 15, and the lowest values were in samples No. 4, 18, 7 and 13 respectively. The results of sugars were lower than those obtained by Zhang,C *et al*In general, All values were higher than the allowed value except for samples No. 6, 13, 5,4, and 18, whose values were 9.2, 11.25, 7.25, 5.46, and 9.74 mg/kg, respectively the values were less than the permissible limits in Libyan and international standards which were around 12 mg/kg.

Table (4) sugars concentration values of tomato samples.

Sample No.	Mean± STDE mg/kg (Sucrose)	RSD%	Mean± STDE mg/kg (Glucose)	RSD%	Mean± STDE mg/kg (Fructose)	RSD%	Mean±) STDE)mg/kg ,total sugars	RSD %
1	2.46±0.09	3.65	1.93±0.15	0.77	7.6±0.26	3.42	11.9±0.0	0.00
2	5.60±0.47	0.08	3.93±0.06	1.52	3.8±0.17	4.47	13.3±0.0	0.00
3	5.24±0.31	0.59	1.76±0.06	2.85	5.6±0.12	2.14	12.6±0.1	0.79
4	0.56±0.05	0.89	1.88±0.10	2.57	3.02±0.12	3.97	5.4±0.01	0.18
5	3.25±0.32	0.98	4.00±0.10	2.5	0.00±0.00	0.00	7.2±0	0.00
6	5.63±0.50	0.88	2.16±0.06	2.76	1.4±0.06	4.28	9.2±0.1	1.08
7	9.53±0.30	3.14	5.43±0.06	1.10	0.00±0.0	0.0	14.9±0	0.00
8	6.27±0.21	3.01	4.13±0.21	5.08	2.0±0.2	10	12.4±0.2	1.61
9	4.11±0.27	0.65	5.67±0.17	2.99	3.5±0.1	2.85	13.2±0.2	1.51
10	8.09±0.56	0.66	3.50±0.1	2.85	2.4±0.06	2.5	13.9±0	0.00
11	10.60±0.4	3.77	10.23±0.12	1.17	3.4±0.1	2.94	24.2±0.32	1.32
12	9.86±0.17	1.72	2.65±0.21	0.79	5.4±0.15	4.41	17.9±0.52	2.90
13	3.56±0.15	4.21	7.69±0.28	3.64	0.00±0.00	0.00	11.2±0.0	0.00
14	9.77±0.17	1.74	8.76±0.38	4.33	6.2±0.25	4.03	24.7±0.2	0.80
15	12.50±0.10	0.8	10.43±0.15	1.43	4.0±0.21	5.25	26.9±0.01	0.03
16	8.33±0.21	2.52	6.16±0.12	1.94	3.8±0.2	5.26	18.3±0.01	0.05
17	7.96±0.21	2.63	9.86±0.06	0.60	5.1±0.15	2.94	22.9±0.0	0.00
18	8.63±0.15	1.73	1.11±0.06	2.84	0.00±0.0	0.00	9.7±0.02	0.20
19	9.33±0.15	1.60	7.33±0.15	2.04	5.5±0.06	1.09	22.1±0.1	0.45
20	11.23±0.25	2.22	9.03±0.06	0.66	3.9±0.21	5.38	24.1±1.2	4.97

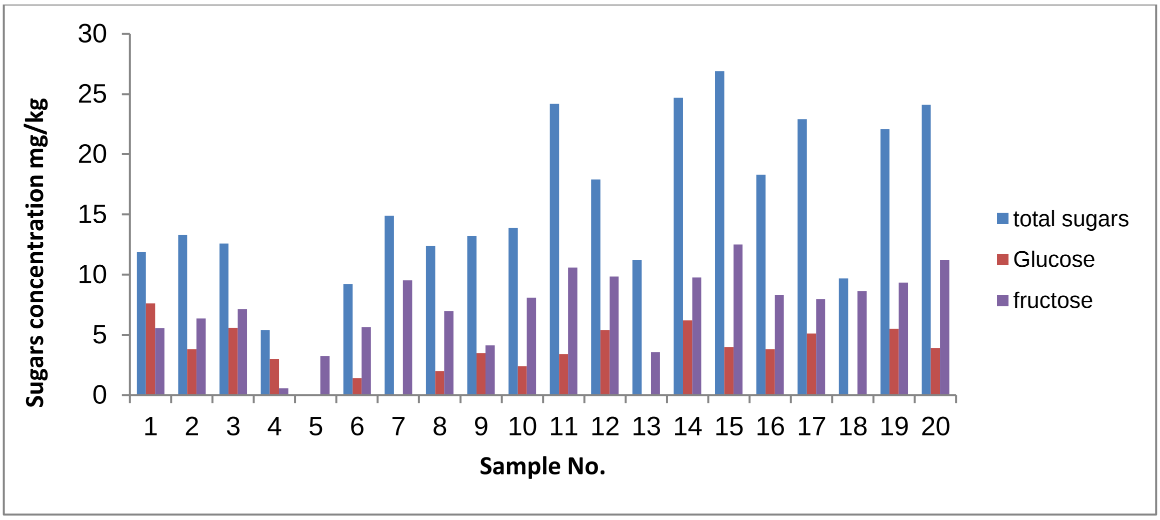

Figure (4): Sugar Concentrations value of studied samples.

Discussion:

- This study concluded with the following results:

According to the results obtained throughout the methodology of the study, it could be said that the pH values were within the internationally and locally permitted values of 4.6 except for sample No. 11, where the value was 5.10, which was the highest value among the samples, as it was close to equivalent. This value made tomato paste vulnerable to the growth of various types of organisms. A microorganism, like *Clostridium botulinum*, is an anaerobic bacteria that causes poisoning.

Total acidity: Generally, the results obtained indicate that it falls within the specifications allowed locally according to the Libyan specifications, which was less than 7%, where the lowest value was for samples No. 13, 19, 0.13%, and the highest value was for the owner of the sample No. 1, 0.17 %. As required by safety regulations acidification of products derived from tomatoes to total acidity of less than 7 %. Sometimes citric acid was added to prevent the activity of microorganisms, and sometimes malic acid was added to improve the product's taste.

According to the obtained results, It was noticed that about 15 samples were higher than the values allowed locally according to the Libyan specification of 12 mg/kg. The rest of samples No. 6, 13, 5, 4, and 18 values fall within the permissible limits, and from here, we could say that there was an increase in the number of sugars; this indicated the addition of an increase in the number of sugars this indicated the addition of several sugars to improve the taste of the product and reduce the acidity during processing. An increase or decrease in sugars indicated a good ripening of sugars, which also varies from one type to another according to the genetic composition.

Recommendation

1. Manufacturers must enforce strict pH regulation (≤ 4.6) to minimize microbial hazards, specifically targeting risks associated with Clostridium botulinum.
2. The incorporation of added sugars should be carefully restricted and monitored to align with both international and Libyan standards, safeguarding product quality and consumer health.
3. Utilization of advanced analytical techniques like Fourier Transform Infrared (FT-IR) spectroscopy can offer substantial reductions in analysis time and costs, all while ensuring precise quality control.
4. Enhance regulatory oversight of local and imported tomato paste products by focusing inspections on key parameters, including pH levels, titratable acidity, and sugar content.
5. Promote consumer awareness regarding healthier product options with optimal sugar-to-acid balances to mitigate the prevalence of diet-related ailments.
6. Undertake further investigations into the influence of agricultural practices—such as fertilization, irrigation, and foliar application—on the sugar-to-acid equilibrium in tomato fruits.
7. Analyze the effects of storage factors—such as temperature, duration, and packaging materials—on the product’s long-term stability and microbial safety.

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