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Effect of Processing on the Characterization of Hot-Break Triple-Concentrated Tomato Paste

Ahmed A. Al-Kafrawy, Yehia Abd El-Razik Heikal, Ihab S. Ashoush, Samar M. Mahdy *

Department of Food Science, Faculty of Agriculture, Ain Shams University, Egypt

Abstract

Tomatoes are one of the most important specialty crops worldwide, and tomato products constitute a significant part of the food industry. Four processing steps were selected for this study to collect the samples. Three samples of four different direct processing steps were collected from tomato paste (Hot-break) to follow changes in some quality characteristics of tomato juice for paste and to investigate some physicochemical (T.S.S., colour, acidity (%) and chlorides), functional components (Vitamin C and Lycopene), rheological and microbiological (TBC, molds and yeasts, lactic acid bacteria, osmophilic yeasts, and Salmonella) properties. The results showed the existence of a highly significant effect of total soluble content and heat treatment (temperature and duration) on the microbial load of the tomato juice and paste. All the results of the tested microbiological characteristics showed a significant increase in the value in the initial stage of treatment before decreasing significantly in the latter part of the treatment. This could be due to the high-temperature treatments and sterilization of the finished product. Also, the study showed that the direct relationship between the concentration and the total soluble solids, rheological properties, colour, chlorides, and acidity.

Keywords: Tomato paste; Tomato processing; hot break; Microbiology criteria; Physicochemical properties;

1. Introduction

Tomato (*Solanum Lycopersicum*) is the second most important cultivated vegetable crop worldwide, especially in Mediterranean countries [1]. All over the world, tomato is being consumed mostly as fresh fruit, and after processing into several products such as tomato juice, tomato paste, sauce, puree, and ketchup [2]. Tomatoes and tomato-based foods are an important part of the world's diet and are found in a large variety of food products imparting both unique appetizing flavour and viscosity. Tomatoes have also been recognized as a source of carotenoids such as lycopene, a very important class of bioactive compounds, especially known for their anti-inflammatory properties and supporting prostate health [3]. Tomatoes to be processed are required to have several qualities such as soluble solids, pH, titratable acidity, viscosity, consistency, colour, sugar, organic acids, and lycopene contents [4]. Tomato paste is used for the colour and taste of food preparations. Tomato pastes are potentially rich sources of dietary phytonutrients that might contribute important health benefits to consumers [5].

Colour is the most important quality criterion in consumer palatability for tomato paste and other food products. It is preferable that the tomatoes used in the production of tomato paste are completely red in both the peel and the fruit [6]. The content of water-soluble dry matter is also one of the most important criteria in tomato paste production. Tomato paste is produced by specifying its Brix value and is offered for sale. A high Brix value indicates that tomatoes with a dry matter content are processed and spent more energy to remove water, while a lower Brix value indicates a cheaper product because it uses less energy to remove the water [4].

The quality of tomato paste depends on the raw materials as well as the processes applied to convert the tomato juice into a paste. In the common production technique of tomato paste, the juice obtained from the fruit moves through a series of evaporators to remove the water at elevated temperatures [7].

Technological treatments applied in the processing industries of tomatoes cause some physical, chemical, and microbial changes. They can cause the modification of the nutritional value [8]. Sterilization schedules optimized and applied influenced the biochemical, technological, and nutritional qualities of triple concentrated tomato paste product according to the method of hold break.

*Corresponding author e-mail: samar_mahdy@agr.asu.edu.eg

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Heat treatments during tomato processing trigger chemical and physical changes which can affect the nutritional and sensorial qualities of final products. Numerous authors studied the influence of processing on tomato antioxidants [9]. Concerning texture, many factors, including variety, maturity, cultural practices integrity of processed tomato products [10]. Colour loss is accelerated by high temperatures and exposure to oxygen during processing. The red colour of tomatoes is mainly determined by the carotenoids and lycopene contents, and the main cause of lycopene degradation is oxidation. During the hot break, the hotter the break temperature, the greater the loss of colour, even when operating under a vacuum [11].

The objective of the study is the characterization of the tomato and tomato paste processing; physicochemical, functional, rheological, and microbiological characteristics as well as the effect of the processing steps on the above-mentioned properties.

2. Materials and Methods

2.1. Materials

Commercially planted tomato fruits (*Solanum Lycopersicum* Cultivar H034) were harvested from commercial fields in Giza and Beni Soif, during the summer of 2021. Samples from five processing steps from independent processing cycles using different independent tomato batches (twenty-one samples from each processing step) were collected from a plant located in 6th of October city during hot-break processing for two years. Figure 1 shows the tomato paste production scheme (arrows outward indicate the sampling steps of the study).

Chemicals and reagents:

Sodium Hydroxide (NaOH), and Phenolphthalein (C20H14O4) from LabChem Inc. Silver Nitrate (AgNO3) purchased from Sigma Aldrich "Merck". Sucrose, Glucose, and Dextrose Agar (PDA) were purchased from Loba Chemie PVT LTD. Buffered Peptone Water (BPW), and Saline Peptone Water (SPW), were purchased from Thermo Fisher Scientific Inc. Tryptone Glucose Yeast Extract Agar, Potato Dextrose Agar (PDA), MRS Broth Powder, and Wort Agar were purchased from Merck Germany for the microbiological examination.

2.2. Methods

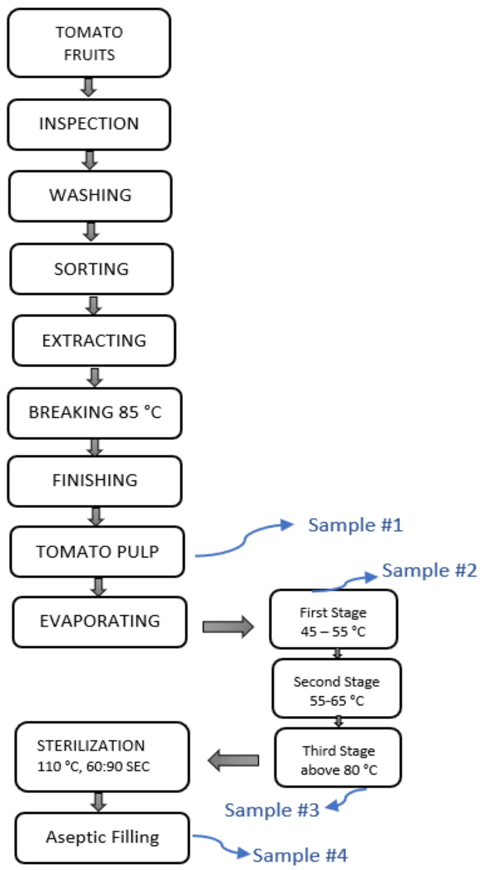
2.2.1. Preparation of tomato paste

Fresh tomato fruits were inspected, washed, and sorted before entering the crusher. Tomato fruits were crushed and extracted at 80 - 95 °C and finished by two strainers of 2.0- and 0.7-mm diameters to remove seeds, skin, and large tomato pieces, followed by a holding period ranging from 60 – 180 seconds during which the enzymes were inactivated. The concentration process went through three stages of evaporation, the first at 45-55°C, the second at 55-65°C, and the last at more than 80°C under vacuum, followed by heating at 110°C then held for 60 – 90 seconds for sterilization and then filled in aseptic bags. The final concentration was about 29 - 31 °Brix.

2.2.2. Physicochemical properties

Total soluble solids (°Brix) was conducted using a digital refractometer (ATAGO RX-7000α – Japan, accuracy ±0.010), and acidity (%) was determined by titration method using 0.1N Sodium Hydroxide solution, and salt content was measured using titration by 0.1N Silver Nitrate solution. The attributes were conducted as described in the AOAC [12]. pH value was determined using a pH meter model (WTW 7110) with a temperature probe [13].

Colour attributes: lightness (L), redness (a), and yellowness (b) of Fresh tomato samples (Juice, evaporator #1) were measured at their original conditions, while paste samples (evaporator #3, filler) were measured at Brix 12 % after being diluted using Hunter Lab spectrophotometer (Hunter Lab Colour Flex EZ) [14].



2.2.3 Functional Compounds

2.3.3.1 Vitamin C

Five grams of each sample was extracted with 100 ml of the Oxalic Acid – EDTA solution, the extract was filtered through a filter paper and then centrifuged. A 5 ml aliquot is then transferred into a 25 ml calibrated flask and mixed with other reagents

0.5ml of the metaphosphoric acid- acetic acid solution and 1 of 5 % V/V Sulphuric Acid followed by 2 ml of ammonium molybdate reagent. After 15 minutes measure the absorbance at 760 nm against a reagent blank [15].

2.3.3.2 Lycopene:

Lycopene was determined spectrophotometrically by extraction with acetone/hexane (4:6) and absorbance measurement at 505 nm [16].

2.2.4. Rheological Properties

2.3.4.1 Bostwick consistency

A sample of unconcentrated 7 °Brix hot-break juice, a partially concentrated sample from the first stage (10 °Brix), and 31°Brix paste, collected on the same day from a commercial processing plant in 6th of October city, were analyzed for Bostwick consistency using a Bostwick Consistometer. The temperature of samples was adjusted to 20 °C, and 70 ml of sample was used for each measurement. The distance traveled by the sample was read after 30 seconds. The results are expressed in cm/30 seconds. Fresh tomato samples (Juice, evaporator #1) were measured at their original characteristics, while paste samples (evaporator #3, filler) were diluted with distilled water to 12° Brix [10].

2.2.4.2. Apparent Viscosity using Brookfield Viscometer:

Apparent viscosity was measured using Brookfield Viscometer (Brookfield Engineering Inc. model DV-II). A 250 ml beaker with a diameter of 7 cm was filled with the tomato sample (Fresh juice, paste) to a height of 9 cm and brought to 20 °C temperature in the TC-500 water bath (Brookfield Engineering Inc.). Measurements were taken 2 min after the spindle (no. 6 at 30 RPM) was immersed to allow thermal equilibrium in the sample and to eliminate the effect

Figure 1: Tomato Paste Processing Flowchart

of immediate time dependence [17].

2.2.5. Microbiological Characteristics

Total Plate Count was determined using a plate count agar [18]. Mold & Yeast was determined using potato dextrose agar [19]. Lactic Acid Bacteria count was determined using MRS agar [20]. Osmophilic Yeast was determined using Wort Agar [21]. Enterobacteriaceae was conducted using Violet red bile glucose (VRBG) agar and a non-selective medium [22]. *Salmonella spp.* Detection was conducted according to the ISO method [23].

2.3. Statistical Analysis

Results are reported as the mean of three replicates ± standard error (SE). Statistical significance between groups was analyzed by one-way ANOVA; followed by Duncan's Multiple Range Test with a significance level set at $p < 0.05$ [24].

3. Results and Discussion

3.1. Effect Of Processing Steps on The Physicochemical Properties

3.1.1 Total Soluble Solids (T.S.S)

The major components of the soluble solids content in tomato products are glucose and fructose concentrations. Total soluble solids content depends on the tomato cultivar and the ripening stage in which the tomatoes are sampled and collected [25]. Early harvested tomatoes usually have higher soluble solids content than later harvested tomatoes and this is consequent with the amount of glucose and fructose, which usually decline over time [26]. Total soluble solids are also yield indicators for tomato producers since higher °Brix means that fewer fruit mounts of fresh fruits are required to obtain a certain quantity of finished product, and less time in the evaporation process is required to eliminate the water from the tomato juice during the concentration process [4]. As seen in Table (1), the samples after sterilization treatment (at the filling step) yielded the highest Brix values at 32.25 % due to concentrate tomato juice to paste through the evaporators. Juice samples had the lowest Brix value (7.2%) since it was exposed to the lowest heat treatment.

Regarding the regulatory point of view, tomato puree must contain 8 to less than 18% of natural total soluble solids however, the concentrated tomato puree should contain 18 % to less than 24% of natural total soluble solids (NTSS), and while tomato paste must contain at least 24% of natural total soluble solids [27].

3.1.2. Colour

Colour is probably the first quality factor judged by tomato product consumers. Thus, an attractive deep red color is a major quality attribute of tomato products [40]. During the hot break, the hotter the break temperature, the greater the loss of colour, even when operating under a vacuum [11]. Also, the use of fine screens in juice extraction enhances oxidation because of the large surface area exposed to air and metal [28].

Colour analysis was performed by a Hunter colorimeter analyzer. The parameter a* takes positive values for reddish colors and negative values for the greenish ones, whereas b* takes positive values for yellowish colors and negative values for the bluish ones. a/b ratio is used to determine the degree of difference of a hue in comparison to grey colour with the same lightness [15]. The higher the ratio values, the higher the colour intensity of samples perceived by humans; thus, the greater value of the a/b ratio indicates a more red colour [29].

As shown in Table (1), during the tomato paste processing the higher the T.S.S % the greater the a/b values and colour quality due to the concentration of the nature tomato soluble solids (N.T.S.S) including the pigments Lycopene and Carotenoids [5].

Table (1): Physicochemical Properties of Tomatoes During Tomato Paste Processing

	Juice Tank	Evaporator #1	Evaporator #3	Filling
Vitamin C mg/100g	9.810 [d] ± 0.849	14.807 [c] ± 1.23	29.80 [a] ± 1.33	23.68 [b] ± 0.65
Lycopene mg/100g	16.643 [d] ± 0.709	24.431 [c] ± 1.706	48.469 [b] ± 2.126	62.145 [a] ± 2.057

Means in the same column with different uppercase letters are significantly different (P≤0.05). Values are mean (n =3)

3.1.3. Titratable acidity and pH Value

Acid content and pH value are important quality parameters that outline tomato products' characteristics such as flavor by defining the tartness component of the flavor which is one of the leading notes in tomato products [25]. Processing conditions further affect the pH value and acidity of processed tomato products.

Table (1) shows that during processing, the pH values decreases and total acid content increases [28], although the citric acid content may increase or decrease [28]. Consistency is affected by the pH value since the pH value modifies the total pectin content and pectin characteristics. Low pH value (~2.5) during breaking and heating results in a larger amount of pectin and a greater portion in the esterified form since pectolytic enzymes are inactivated [25].

3.1.4. Salt content

Chlorides express the salinity of the product. The average salt content of tomato samples during the processing steps (juice and pastes) are summarized in Table 1. The results show that the juice samples had the lowest content of salt whereas the concentrated tomato samples have the highest values with no significant increase between the third evaporator and filling (finished product) samples.

3.2. Effect of Processing Steps on The Functional Compounds

3.2.1 Vitamin C

L-ascorbic acid is one of the most important antioxidants in fruits and vegetables, exerting a crucial role in the detoxification of reactive oxygen species generated in the human body [30]. Data in Table (2) indicates that vitamin C content has increased during the tomato paste processing this could be a result of the concentration increase. However, although the filling has a very similar brix value (32.25 %) as the evaporator #3 (31.25 %), filling sample has a lower content of Vitamin C due to the high temperature exposure at 110 °C/60 seconds. It has been reported that temperature, pH value, and the duration of treatment are the principal parameters affecting the degradation of this compound [31]. Vitamin C content decreased as the processing times increased in the paste samples (Evaporator #3 and Filling) therefore, recommending that it does not require excessive heat treatment [47].

3.2.2 Lycopene

Tomato matrix disruption by mechanical homogenization or heat treatment of tomato increases lycopene bioavailability [32]. Oxidation and thermal degradation of lycopene occurred at high temperatures and processing times beyond 90 minutes [33]. Similarly, it was reported that excessive heat treatment negatively affects the lycopene content of tomatoes [34].

The carotenoid mainly found in red tomatoes is (E)-lycopene. The latter is the most stable form of the thermodynamic point of view. It is their main pigment [35]. Most of the lycopene content is found in the skin and pulp. It is the main responsible for the red colour of tomatoes. With these 11 conjugated double bonds and two unconjugated lycopene is 100 times more effective than α-tocopherol as an antioxidant [36].

Table (2): Effect of Processing Steps on the Functional Compounds of Tomato

Process Step	Temp. °C	T.S.S %	Colour				pH Value	Total acidity %	Salt %
			L	a	b	a/b			
Juice Tank	65.9	7.2 [d] ± 0.058	24.94 [b] ± 0.222	23.635 [b] ± 0.136	12.995 [a] ± 0.009	1.82 [d] ± 0.012	4.66 [a] ± 0.012	0.50 [d] ± 0.009	0.135 [c] ± 0.003
Evap. #1	49.45	9.8 [c] ± 0.058	24.58 [b] ± 0.017	23.89 [b] ± 0.052	12.595 [a] ± 0.095	1.90 [c] ± 0.019	4.615 [b] ± 0.014	0.67 [c] ± 0.005	0.18 [b] ± 0.0
Evap. #3	83.33	31.25 [b] ± 0.20	24.68 [b] ± 0.21	24.75 [b] ± 0.21	12.6 [a] ± 0.30	1.97 [b] ± 0.03	4.51 [c] ± 0.011	1.95 [b] ± 0.02	0.54 [a] ± 0.006
Filling	after sterilization at 110 °C /60 Sec	32.25 [a] ± 0.087	25.64 [a] ± 0.11	29.05 [a] ± 0.85	13.345 [a] ± 0.32	2.175 [a] ± 0.09	4.45 [d] ± 0.0	2.09 [a] ± 0.012	0.56 [a] ± 0.017

Means in the same row with different uppercase letters are significantly different (P≤0.05). Values are mean (n =3)

As shown in Table (2), the Lycopene content has significantly increased during the tomato paste processing and concentration. Some of the previous studies performed on the effects of the heating process on Lycopene of tomato and tomato paste reported that Lycopene amount increased with heating & processing steps [37]. Similarly, heating tomato pulp at 110 °C for 60 Seconds (after the evaporation process prior to the filling step) caused a significant change in lycopene amount.

3.3. Effect of Processing Steps on The Rheological Properties

3.3.1. Consistency Using Bostwick

Tomato concentrate is manufactured by vacuum evaporation of tomato product to 28˚ Brix % (TSS), or above. Some studies suggested that the Bostwick value decreased logarithmically with the degree of paste concentration [38].

As shown in Table (3) the Bostwick readings of tomato paste decreased exponentially with increasing the concentration, which imposes a limit on the validity of this method on tomato concentrates with more than 15% total solids [39]. With a similar Brix between the third evaporator and filling point samples, there is no significant decrease in the consistency between both.

3.3.2. Apparent viscosity using Brookfield

Tomato juice is considered as a non-Newtonian fluid since its resistance to shear force is not linearly related to the rate of shear apply to it [25]. In addition, viscosity is used to assess and optimize unit operations such as mixing, pumping, and filling [41], hence it can be used to reduce costs and improve companies' profits. According to the amount and type of pectin present in the tomato products, different viscosities can be achieved. In addition, this important textural parameter is affected by pectolytic enzymes which are inactivated by heat to avoid pectin depolymerization which would decrease the viscosity of tomato pulp or serum [25]. Therefore, processing temperature has a strong influence on tomato products' viscosity, since the amount of heat defines the degree of inactivation of these enzymes; higher break temperatures result in higher viscosity [40]. Pectin significantly influences the textural and rheological characteristics of tomato paste, because of its great thickening and gel-forming properties, and during the (hot) method operation, the temperatures are high enough for pectolytic enzyme inactivation, and this leads to a concentration of greater viscosity [5].

Tomato paste samples collected from evaporator #3 and filling points had a significantly higher viscosity (5558 and 5811 cps, respectively) than juice sample.

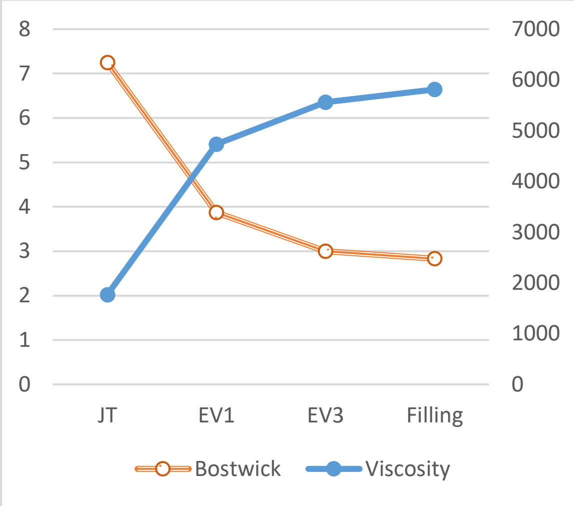


Figure 2: The relationship between apparent viscosity and Bostwick during the tomato paste HB processing

3.3. Effect of Processing Steps on The Microbiological Properties

Food-borne pathogens are the leading cause of illness and death in developing countries, and they create a great financial effect on medical care and social life cost [42]. Several studies have reported explosions of food-borne diseases associated with tomatoes [43]. These outbreaks are usually due to the consumption of contaminated produce and poor hygienic practices.

Tomato is a fruit that is highly perishable due to its high-water content and hence prone to spoilage by microorganisms. The activities of these microorganisms bring about high levels of postharvest losses [44]. Due to their nature and perishability, tomatoes are more susceptible to infection due to their shape, structure and relatively soft texture associated with high humidity, which leads to deterioration of transit and storage which is faster under conditions of high temperature and humidity, hence, heavy losses are encountered [45].

The microbiological examination was done on Total Bacterial Count, Mold & Yeast, Lactic Acid Bacteria, Osmophilic Yeast, and *Salmonella spp.* The results in Table (4) indicate that neither bacteria nor yeast & mold growth were detected in concentrated tomato puree samples (Finished product from the filling point) which complies with Egyptian Standards Codex Stan [27, 46].

Table (3): Effect of Processing Steps on The Rheological Properties

	Juice Tank	Evaporator #1	Evaporator #3	Filling
Viscosity cps	$1767^{d} \pm 22$	$4733^{c} \pm 694.4$	$5558^{b} \pm 48.70$	$5811^{a} \pm 40.22$
Bostwick cm/30 sec	$7.25^{a} \pm 0.0$	$3.875^{b} \pm 0.083$	$3.0^{c} \pm 0.0$	$2.833^{c} \pm 0.83$

Means in the same row with different uppercase letters are significantly different (P≤0.05). Values are mean (n =3)

Table (4): Effect of Processing Steps on The Microbiological Criteria of Tomato Paste

Process Steps	Temp. °C	TBC CFU/gm	M&Y CFU/gm	Lactic Acid Bacteria CFU/gm	Osmophilic Yeast CFU/gm	Salmonella Spp. -/+
Juice Tank	65.9	$1.5x10^3$	$7x10^2$	$1.42\ x10^3$	$2.5x10^1$	ND*
Evaporator #1	49.45	$>3x10^5$	$>3x\ 10^4$	$>3x\ 10^4$	$5x10^1$	ND*
Evaporator #3	83.33	$1.15x10^2$	$2x10^1$	$3x10^1$	$1x10^1$	ND*
Filling	after pasteurization at 110 °C /60 Sec	$< 1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^1$	ND*

ND: Not Detected

Means in the same column with different uppercase letters are significantly different (P≤0.05). Values are mean (n =3)

The results of the attributes tested in Table (4) show a significant increase in value at the initial phase of processing before it reduced significantly at the later part of the processing. This could be a result of the high-temperature treatments and sterilization of the finished product. Although evaporator #1 samples have greater total soluble solids than juice tank samples, and a higher microbial load (TBC, molds & yeasts) this could be a result of the long-incubated time the product spent inside the pipes at the optimum temperature required for the growth of mesophilic bacteria [16].

4. Conclusion

This study showed that the physicochemical, rheological, and microbiological properties of tomato juice/paste are affected by the heat treatment and concentration process.

The samples after sterilization treatment (at the filling step) yielded the highest Brix values at 32.25% due to concentrating tomato juice to paste through the evaporators. However, juice samples had the lowest Brix value since they were exposed to the lowest heat treatment at 65.9. Colour loss is accelerated by high temperatures and exposure to oxygen during processing. During the tomato paste processing, the higher the T.S.S, the greater the a/b values and colour quality due to the concentration of the natural tomato soluble solids (N.T.S.S), including the pigments (lycopene and carotenoids). The concentrated tomato samples had the highest values of acidity and chloride content, with no significant increase between the evaporator #3 and filling (finished product) samples.

Thermal processing makes the lycopene more available in processed tomatoes. This nutritional information could be a guide to processors and consumers of tomato products. Lycopene and Vitamin C amounts are increased because of the concentration steps from juice tank samples to paste samples (final evaporation and filling steps). However, Vitamin C content decreased as the processing times increased in the paste samples (Evaporator #3 and Filling) therefore, recommending that it does not require excessive heat treatment.

Tomato paste samples collected from evaporator #3 and filling points had a significantly higher apparent viscosity and decreased Bostwick values than juice samples due to the high T.S.S content.

The results of the tested microbiological attributes showed a significant increase in values during the first phase of processing before decreasing significantly later in the process. This could be a result of the high-temperature treatments and sterilization of the finished product.

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