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Effects of Pre-Heating and Concentration Temperatures on Physico-Chemical Quality of Semi Concentrated Tomato (*Solanum lycopersicum*) Paste

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Abstract

Fresh tomato is one of the fruits with a short shelf life. The purpose of this study was to evaluate the effects of pre-heating and concentration temperatures on the physicochemical and microbiological quality attributes of semi-concentrated tomato paste. Breaking temperatures of 60°C, 70°C and 90°C for 7 min and concentration temperatures of 80°C and 90°C were used to prepare semi tomato paste of 13-degree Brix of Total Soluble Solids (TSS). TSS, titratable acidity, pH, lycopene, vitamin C, viscosity were determined following standard methods. Increasing breaking temperature and concentration temperatures significantly ($p<0.05$) increased TSS, viscosity, and lycopene content, but reduced significantly ($p<0.05$) vitamin C content. The hot broken tomato at 90°C and concentrated at 90°C caused a significant reduction of vitamin C content (44% loss) as compared to the other treatments of tomato paste samples but greater product consistency (gross viscosity) and higher lycopene content. Processing conditions have a great influence on the overall quality of the final product. The breaking process at 70°C and concentrating at 80°C shown good viscosity and better retention of vitamin C. Therefore, breaking at 70°C and concentrating at 80°C can be adopted for commercial production of tomato paste.

Keywords: Semi-concentrated tomato paste; Breaking; Concentration; Physicochemical

Introduction

Tomato (*Lycopersicon esculentum*) is an important vegetable crop grown in many countries across the world for fresh market and multiple processed forms [1]. It is considered as an important cash generating crop for smallholders and medium scale commercial farmers and provides employment opportunity in the production and processing industries [2,3]. Tomato consumption also makes significant contributions to human nutrition throughout the world [4]. Tomatoes, commonly consumed in daily diets, are a major source of antioxidants, which have a greater contribution to a well-balanced healthy diet with the right proportion of vital nutrients such as minerals, vitamins, essential amino acids, sugars, lycopene, and other carotenoids and dietary fibers [5-7].

Tomato paste is commonly produced by the hot-break processing method: a rapid deactivation of pectolytic enzymes during the hot-break process is considered essential to prevent demethylation and break-down of pectin molecules [8,9]. The consistency of the product also depends on the bio-availability of various compounds, such as pectin and other hydrocolloids (e.g., hemicelluloses). If the initial product is rich in these hydro-colloids, and subsequently evaporated to produce tomato paste, it results in a high consistency tomato paste [10].

Fresh tomato has a limited storage life 2-3 weeks under ambient temperature and cannot be stored over extended periods. To minimize after harvest losses, the tomato is processed in the forms of paste, juice, ketchup, sauce, and purée [11]. Possible preservation methods of tomato include physical (application of heat, irradiation, and Soundwave) and chemical preservatives or combinations of those different means of methods [12]. Among these preservation methods, thermal processing is one of the most common and effective means. It is widely used to produce a number of fruits and vegetable products. Concentrated pastes are usually stored and used as an intermediate product with water and other ingredients to be reconstituted into final products, such as ketchup and sauces. Since tomato paste is the main ingredient in the final products, maintaining the quality of the paste is crucial for the tomato processing industry. Factors like the cultivar of the tomato and the processing conditions introduce great variation in the quality of the paste [13].

Many researchers have reported that the use of novel thermal processing like ohmic heating, high frequency heating and microwave heating application in fruits and vegetable processing and its effect on their quality, for example in carrot juice [14], carrot pieces [15], Brussels sprouts [16,17], potato [18,19], peas and spinach [20], tomato, Swiss chard and green beans, asparagus [21], and sweet potato purees. However, in most of these publications, the research was carried out at industrial level by oven or a simply modified microwave oven with specially installed temperature sensors.

Processing and preservation techniques used for tomato paste are very crucial in determining the different post-harvest quality attributes of tomato fruit such as soluble solids, sugar, acidity, pH color, and firmness both in fresh market and processed tomatoes [22]. Many studies have been conducted on tomato products which include,

- Heat treatment effect on the tomato paste technological quality [23]
- Evaluation tomato varieties for ketchup processing [24]
- Cooking times and temperature effects on tomato sauce lycopene content [25]
- Thermal processing effect on vitamin C and
- TSS of tomato juice [26]

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However, the effect of conventional heat processing of tomato paste on physicochemical and microbial quality is not yet explored.

Heat processing of tomato paste involves pretreatment (breaking) and concentration. Preheat treatments are often carried out at temperatures of 60°C-100°C to for the action of enzymes such as Pectin methylesterase (PME) and Pectinesterase (PE) in time range 1-5 min [27]. Concentration involves driving off moisture and is normally 80°C-100°C [28]. Heat processing; however, may affect color retention, nutrient retention and various physicochemical properties of the paste such as viscosity, acidity, and TSS, among others [12]. Adequate processing temperatures should, therefore, be selected for different products to ensure better color retention, nutrient retention and attaining the desired physicochemical attributes.

Materials and Methods

Description of the study area

This study was conducted in small holder tomato seed producing farmers at Hawassazuria, SNNPR, Ethiopia. Laboratory analysis was conducted in Food chemistry and microbiology laboratory at the School of Nutrition Food Science and Technology, College of Agriculture, Hawassa University.

Experimental design and treatments

A factorial experimental design of two factors (3 of levels breaking and 2 of levels concentration) was used to determine the effect on physicochemical quality of semi-concentrated tomato paste. Cold, Normal and Hot break at 60°C, 70°C and 90°C were used. The concentrate in the process was done at 80°C and 90°C. Concentration was carried out until a TSS content of ≥ 13% conventionally. This experiment has six treatment combinations (3 × 2), and all the parameters (quality indexes) were done in triplicate.

The treatments were CB-C_1 (Cold beak at 60°C and concentrated at 80°C)-T_1; CB-C_2 (Cold beak at 60°C and concentrated at 90°C)-T_2; NB-C_1 (normal break at 70°C and concentrated at 80°C)-T_3; NB-C_2 (normal break at 70°C and concentrated at 90°C)-T_4; HB-C_1 (hot break at 90°C and concentrated at 80°C)-T_5 and HB-C_2 (hot break at 90°C and concentrated at 90°C)-T_6 (Figure 1).

Fully ripe tomato fruits Roma variety were purchased from Jitu Horticultural Center, Hawassa, Ethiopia.

Sample preparation

Sorting and cleaning: The parameter used for tomato sorting is color and physical state of fruits. Therefore, the ripe tomato fruits of uniform size were selected and they have been sorted out to eliminate bruised, punctured and damaged one. Washing is a critical control step in the processing of tomato products with a low microbial count. The ripe tomato sample was washed with potable water to remove dirt, mold, insects, and other contaminants. The sorted tomatoes were then

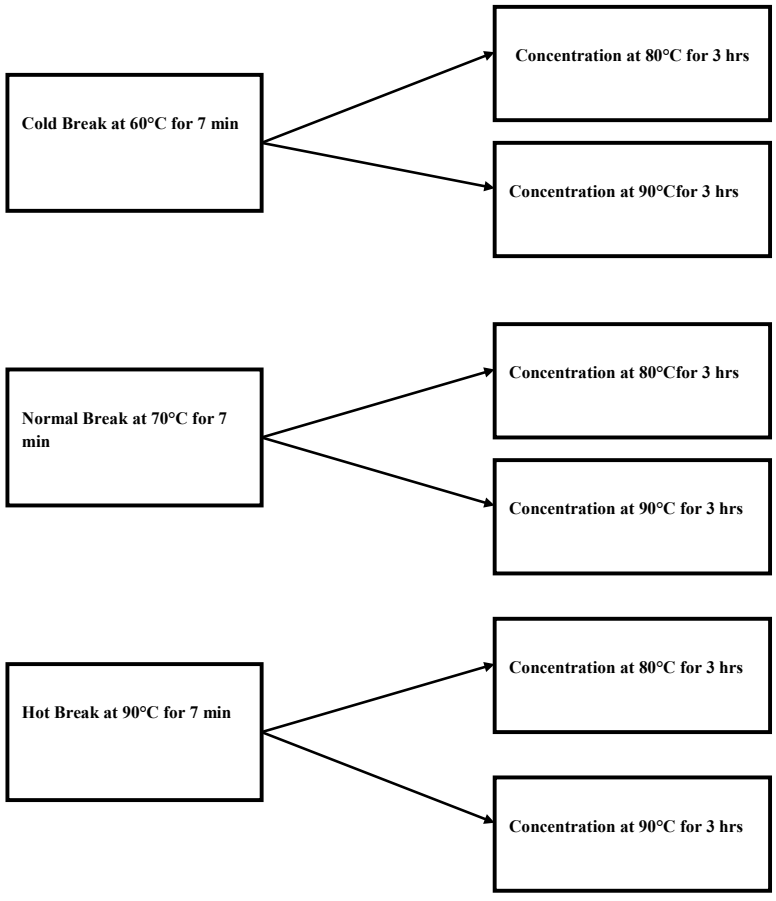

Figure 1: Flow diagram for treatment combinations.

washed under potable water. The cleaned tomatoes were individually cut into four quarters and the seed and pulp removed manually by using a clean knife. The seed and peel removed pulp further copped and crashed by fruit juices.

Breaking: The seed and peel removed pulp further copped and crashed by household juicer then three break temperatures were used as a cold break at 60°C, normal break at 70°C and hot break at 90°C for the action natural enzymes for 7 min to all the breaking temperatures [29].

Evaporation: After sorting and effective cleaning, the tomato paste entered in the evaporation process. The tomato paste was evaporated at 80°C and 90°C to achieve 13°Bx of TSS concentration in conventional techniques by kitchen saucepan at atmospheric pressure for 2.5-3 hours. This is done after the respected breaking.

Pasteurization: After evaporation, the tomato paste was filled in previously sterile screw sample jars and pasteurized in a water bath at 100°C for 14 minutes, in atmospheric pressure. The pasteurized tomato paste was cooled and stored at ambient temperature. This process was done after concentration. The tomato paste was prepared as illustrated in Figure 2.

Analyses of samples

The processed semi-concentrated tomato paste was characterized for the physicochemical (TSS, pH, titratable acidity, viscosity, vitamin C and lycopene content), qualities are described below.

Physicochemical quality analysis of the tomato paste

pH: The pH of the semi-concentrated tomato paste samples were determined as per the method described by AOAC [30]. Measurement of the pH of the sample was done by digital pH meter (Model Thermo scientific Orion Star TM and Star plus Meter, China), which was first standardized by using buffers solutions of 4.0 and 7.0 pH values.

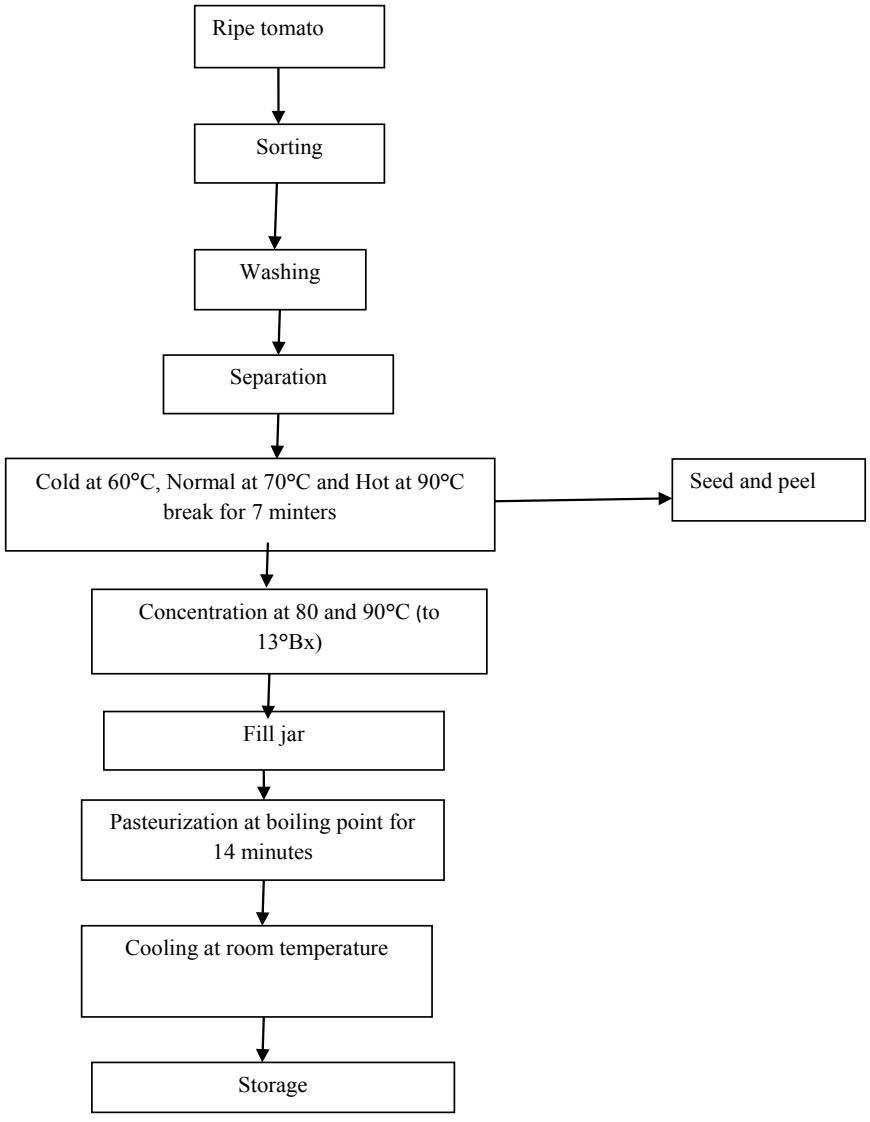

Figure 2: Diagram showing the processing steps of semi concentrated tomato paste.

Titratable acidity: The titratable acidity was measured by the method described by the Association of Official Analytical Chemists (AOAC) [30].The titrable acidity (expressed as citric acid %) was determined by titrating 10 mL of the semi-concentrated tomato paste samples (diluted with 10 mL of distilled water and boiled to evaporate the CO_2) with 0.1 N sodium hydroxide, using phenolphthalein as an indicator. During titration as tomato colorful fruits, the pH was measured up to 8.03 to decide the end point of the titration. The titratable acidity was expressed as percent of citric acid by using the following formula:

Titrable acidity(% Citric acid) = $(V_{NAOH} \times C_{NAOH} \times 0.070 \times 100)/V_{sample}$

Where V_{NAOH} =tritratable volume of solution; V_{sample} =tritratable volume of sample; C_{NAOH} =Concentration of NaOH solution.

TSS: The TSS were determined by digital sugar/Brix refractometer 0-32% W/ATC, 300010, Sper Scientific, China) a resolution of 0.2°Bx by placing 1-2 drops. The semi-concentrated tomato paste sample was thoroughly mixed to make a homogeneous mixture. A drop of semi-concentrated tomato paste is placed on the prism of the refractometer and direct reading was taken by reading the scale in °Bx. This is equivalent to the total amount of soluble solids content. Between samples, the prism of the refractometer was washed with distilled water and dried before use. The refractometer was standardized against distilled water (0°Bx).

Viscosity: The viscosity of semi-concentrated tomato paste was measured using a brook filed viscometer (programmable rheometer model DVIII, Brookfield, USA). The semi-concentrated tomato paste samples (about 10 mL) were poured into the viscometer beaker, cooled to 40°C and viscosity measured (in centipoise, cp) using spindle number 5 at a shear rate of 6 Revolutions Per Minute (rpm). The average of the maximum and minimum viscosity reading was recorded.

Vitamin C: The content of vitamin C was determined by Redox titration using iodine solution. A 20 mL aliquot of the sample solution was pipetted into a 250 mL conical flask and about 150 mL of distilled water was added and 1 mL of starch indicator solution. The sample was titrated with 0.005 mol per liter of iodine solution. The endpoint of the titration was identified as the first permanent trace of a dark blue-black color due to the formation of the starch-iodine complex.

$$\text{Ascorbic acid (mg)} = ML_{\text{Iodine solution}} \times ML \times 176.12\text{g/Mol}$$

$$M_{\text{Iodine solution}} = \text{Mass ascorbic acid} \times \text{mol}_{\text{ascorbic acid}} /$$

$$176.12\text{g of ascorbic acid} \times 10^3\text{mL/vol. of iodine solution}$$

Lycopene content: The reference method of the determination of lycopene content is standardization of a Rapid Spectrophotometric Method for lycopene analysis proposed by the California League of Food Processors and recommended by Department of Food Science and Technology of the University of California-Davis. The methodology consisted of the extraction of lycopene present in the sample with a solution of Hexane:Ethanol: Acetone (HEA) in the proportion of 2:1:1. Then, the lycopene extract was separated in an organic phase adding distilled water and then the lycopene absorbance was read at the wavelength of λ=503 nm in the spectrophotometer. To zero the spectrophotometer prepares one or two samples with 100 µL water instead of tomato paste. It is important that the glass cuvette is rinsed with the hexane layer from this zero sample prior to reading the lycopene absorbance.

Quantification of lycopene was performed by spectrophotometer model (Cintra 20, UV-Visible GBC) which determine the concentration of lycopene in the extract. The determination of the upper layer volume was based on the following formula. According to Beer's Law, the optical absorbance (at λ=503 nm) of a lycopene solution is proportional to the lycopene concentration which is the amount of lycopene per volume.

In this case, the Lambert-Beer law can be described as:

A503 = ε (M^{-1} cm^{-1} b (cm) × (Lycopene concentration (M))

Lycopene content (mg/kg) = 137.4 × A503

Where, A503-Absorbance at λ=503 nm, ε-Coefficient of extinction and b-cell length.

Data analysis

Data were represented as means ± standard deviations of triplicates. All collected data were subjected to analysis by using one way of Analysis of Variance (ANOVA) using SAS software program (version 20). Mean separation was done using Least Significant Difference (LSD) at $p<0.05$.

Results and Discussion

Breaking and concentration effect on the physicochemical quality of semi-concentrated tomato paste

The results of the physicochemical quality analysis for raw tomato as a control sample and semi concentrated tomato paste are shown in Table 1.

Breaking and concentration process effect on the pH and TA: From the results of the study, it was obtained that the pH of the tomato paste was found relatively in lesser range (i.e., 4.21-4.28) as compared to the tomato juice of control sample having higher pH (4.33) (Table 1). The maximum pH value among the treatments was observed at T_1 ($CB\text{-}C_1$) which is (4.28), followed by T_2 ($NB\text{-}C_2$) (4.26), and least at T_6 ($HB\text{-}C_2$) (4.22) (Table 1). There is no significant change at $p<0.05$. Heat treatment did not significantly affect the pH during breaking

Treatments	pH	TA (% citric acid)	TSS (°B)	Viscosity (cps)	Vitamin C (mg/100 g)	Lycopene (mg/100 g)
$CB\text{-}C_1(T_1)$	4.28 ± 0.03^a	0.33 ± 0.00^c	12.81 ± 0.02^c	370.0 ± 4.36^d	37.52 ± 0.38^a	3.10 ± 0.16^b
$CB\text{-}C_2(T_2)$	4.26 ± 0.10^a	0.33 ± 0.01^c	12.85 ± 0.02^c	379.7 ± 3.51^d	36.81 ± 0.13^a	3.12 ± 0.09^b
$NB\text{-}C_1(T_3)$	4.25 ± 0.08^a	0.34 ± 0.00^b	13.03 ± 0.06^b	440.3 ± 11.6^c	35.23 ± 1.00^b	4.23 ± 0.24^a
$NB\text{-}C_2(T_4)$	4.24 ± 0.11^a	0.35 ± 0.00^b	13.08 ± 0.13^b	460.3 ± 2.08^b	34.82 ± 0.20^b	4.30 ± 0.13^a
$HB\text{-}C_1(T_5)$	4.21 ± 0.07^a	0.36 ± 0.01^a	13.32 ± 0.04^a	470.3 ± 3.51^b	29.90 ± 1.45^{bc}	4.45 ± 0.19^a
$HB\text{-}C_2(T_6)$	4.22 ± 0.01^a	0.36 ± 0.01^a	13.25 ± 0.03^a	489.7 ± 8.39^a	27.70 ± 0.32^c	4.50 ± 0.23^a
Control	4.33 ± 0.01	0.32 ± 0.02	4.89 ± 0.02	Not detected	42.8 ± 0.20	1.95 ± 0.01

Values are means ± standard deviations of the triplicates determinations. Values in the same column with the same superscripts (a, b, c) are not significantly different at $p<0.05$.

Table 1: Breaking and concentration process on the physicochemical quality of tomato paste.

and concentration process of tomato paste. In the current study, there is a slight difference in titrable acidity of the treatments in processing tomato paste, which is in the range of 0.33-0.36 (Table 1). The current study is in line with other studies by Nirupama and Tilahun [31], which indicated that the fluctuations of pH might be due to the variations in titratable acidity or temperature of breaking and concentration process and the decline of acidity is attributed due to increased activity of citric acid. Deolinda [32] also reported that heat treatment did not significantly affect pH and acidity during tomato processing. The current study also is in line with Hui et al. [33] who reported that the acidity of tomato which is expressed as citric acid content can smoothly change during heat processing. In another report, it was indicated that the quality of organic acids expressed as citric acid decreased in other fruit pulp during thermal heat treatment [34]. Furthermore, the inhibition of enzyme activity by high evaporation temperatures could explain the delay in loss or depletion of organic acids in the enzymatic reactions.

Breaking and concentration effect on TSS and viscosity: The effect of breaking and concentration processes on TSS and viscosity was shown in Table 1. Among the treatments, T_5 (HB-C_1) has high TSS value (13.32°B) followed by T_6 (13.25°B) and the least TSS value was observed in T_1 which was 12.81°B. The results of the TSS value showed a significant change at $p<0.05$. The current study result on TSS is in agreement with the earlier study reported by Shalaby et al. [34], who stated that the percentage of total sugars was significantly affected by the breaking process. The present results are also in line with an earlier report by Cheour et al. who reported the concentration of free sugars progressively increased with storage and this increase was quite markedly delayed by heat treatment.

In the present study the viscosity of tomato paste, treatment T_6 (HB-C_2) shown the highest value 489.7 cps. T_5 followed by 470.3 cps and the least value was observed at T_1 (370 cps). Processing of tomato at different breaking temperatures (60°C, 70°C and 90°C) and concentration at (80°C and 90°C) caused significant changes in tomato paste viscosity at ($p<0.05$). The viscosity of tomato paste in the current study increased as the breaking temperature increased due to might be the cold break temperature accelerates the enzymatic activity of PG and PME. While the hot breaking temperature inactivates those enzymes degradation action of the cell wall materials at the same holding time. The increase in viscosity of the tomato paste is also related with as more energy supplied at a higher temperature thus resulting in more water being evaporated off to concentrate the product. Thus different temperatures might affect its rheological properties [35]. Inactivation of pectolytic enzymes by heat also results in significantly higher values of serum and efflux viscosity [11,36].

In another study by Deolinda [32], it was reported that the consistency of tomato purees vary depending on a number of factors including the ripening stage of the tomato fruits and processing conditions. And also Bayod et al. [35], who conducted study on the rheological behavior of tomato products at low concentrations, resulting in evidence that many factors play a role in determining the consistency of tomato products including the degree of maturity, particle size, and particle interactions, content of solids and temperature of processing.

Breaking and concentration process effect on Vitamin C and lycopene: The vitamin C and Lycopene content of tomato paste processed at cold, normal and hot breaking and concentration at 80°C and 90°C were given in Table 1. The vitamin C content of T_1 (CB-C_1) was 37.52 mg/100 g followed by T_2 (36.81 mg/100 g). The least value of vitamin C was observed in T_6 (32.70 mg/100 g). The control sample had 42.8 mg/100 g of vitamin C content. In the present study, the vitamin C content decreased as a result of the breaking process changed from cold to hot process and also as concentration temperature increases from 80°C to 90°C. There were significant differences in vitamin C content of the tomato pastes. Breaking heat treatment caused significant changes in tomato paste vitamin C at $p<0.05$. The current study is consistent with Jacob et al. [37], who reported that domestic cooking might cause greater losses of vitamin C than the industrial production of tomato paste. The reason might be the industrial process was carried out under vacuum, whereas, domestic cooking occurs under normal atmosphere. In the current study, the decrease in vitamin C content was due to the fact that vitamin C is heat liable. The current study is also in agreement with Jacob et al. [37], who indicated that cooking at high temperature might cause greater losses of ascorbic acid in the production of tomato paste. There was about 44% of the loss of vitamin C in the hot break and concentration processing in the current study. In other studies conducted by Barringer [38], stated that during hot-break extraction, tomato lost about 38% of the original ascorbic acid. That's happened too when the duration of the process is a long time low temperature and short time high-temperature profiles.

In the current study, the lycopene content of T_6 (4.50 mg/100 g) and followed by T_5 (4.45 mg/100 g). T_1 shown lower lycopene content 3.10 mg/100 g. The control sample had the lowest lycopene content 1.95 mg/100 g. From the results of the present study, lycopene concentration increases with increasing temperature of breaking and concentration process temperature at $p<0.05$. This reveals that heat is facilitating the release of lycopene from the tomato cell matrix. The present finding is in agreement with the study conducted by Barringer [38] and Lavelli et al. [39], who described lycopene concentration increase by the thermal processing of tomatoes in the production of tomato paste. The current study is also in line with Deolinda [32], who described the lycopene concentration increases with increasing processing temperature [40-42].

In another study, it was found that contents of lycopene on a wet weight basis increased during thermal processing of tomato paste. The current study showed that, the lycopene concentration increase with increasing process temperature and ascorbic acid concentration decrease in the same order.

Conclusion

Breaking at 60°C (cold break), 70°C (normal break) and 90°C (hot break) and concentration process at (80°C and 90°C) of tomato had a significant effect on most of the physicochemical quality of semi-concentrated tomato paste.

The hot broken tomato at 90°C and concentrated at 90°C (HB-C_2 or T_6) caused a significant reduction of vitamin C content (44% loss) as compared to the other treatments of semi-concentrated tomato paste samples but greater product consistency (Gross viscosity) and higher lycopene content. Processing conditions have a great influence on the overall quality of the final product. Sample breaking at 70°C and concentrating at 80°C showed good viscosity and better retention of vitamin C. Therefore, breaking at 70°C and concentrating at 80°C can be adopted for commercial production of tomato paste.

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