J. Agric. Sci. Mansoura Univ., 31 (12): 7797 -7808, 2006

ALTERATION IN TASTE-ACTIVE COMPOUNDS OF TOMATO PRODUCTS DURING PROCESSING

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ABSTRACT

Substances (such as sugars, acidity, minerals, free amino acids, peptides and proteins) affected on the taste of tomato juice and its products were investigated. Results revealed that total solids of tomato juice gradually increased by heat treatment. Whereas, total solids of tomato paste was significantly higher than that pasteurized juice and the latter was higher than that of non-pasteurized one. Total reducing sugars of tomato non-pasteurized juice, pasteurized juice and paste, made up mainly from glucose and fructose which they occurred in a ratio near to 1:1. A slight decrease in the reducing sugars content was observed in tomato paste. The titratable acidity of pasteurized juice was (12.22g as citric acid /100g SS) slightly higher than that of non-pasteurized one (11.99g as citric acid /100g SS), while the lowest titratable acidity (1.29 g as citric acid /100g SS) was detected in tomato paste. At the same time, pH values of their serum were mostly identical. Soluble mineral content of tomato products slightly increased as a result of heat treatment (pasteurization and concentration). Total mineral content (6.00g/100g SS) consisted of potassium (4.81g/100g SS), magnesium (0.321g/100g SS), calcium (0.17 g/100g SS), sodium (0.07 g/100g SS) and phosphorus (0.591g/100g SS). More than 80 % of the nitrogen content could be derived from soluble compounds present in the serum. The percentage of nitrogenous constituents increased in the paste comparing with both non - pasteurized and pasteurized juices. Glutamic, glutamine, γ- amino butyric and asparatic acids made up 72 % of the total free amino acids in non-pasteurized juice. Threonine, lysine and phenylalanine were the main essential amino acids in non-pasteurized tomato juice. Which increased in tomato products due to heat treatment. Nevertheless, peptide content of non-pasteurized juice was 8.5 g/100g SS increased to 10.1 g/100g SS in tomato paste.

Keywords: tomato, taste compounds, sugars, minerals, free amino acids, nitrogen content.

INTRODUCTION

Tomato *(Lycopersicon esculentum)* fruit is one of the most favorite vegetables, which is consumed either as fresh fruits or as processed products. Epidemiological studies showed a relationshipe between dietary intake of tomatoes and its products and decrease a risk of chronic diseases due to antioxidant properties (Ragab *et al*, 2006; Tiziani *et al*, 2006). The annual worldwide production of processed tomato fruits is about 20 million tons, which represents more than 80 % of the gross product (Gould, 1992; Thakur *et al*, 1996). Tomato's flavor depends, mainly, on the combination of volatile compounds for odor and both total sugars and organic acids ratio for taste (Stevens, 1985; Petro-Turza, 1987; Baldwin *et al*, 1991a & b and Tandon *et al*, 2003). It is well known that total solids of tomato fruits ranged from 5.0-7.5%, where reducing sugars (fructose and glucose) represent 45-50% of tomato's total solids (Goose and Binsted, 1973; Stevens *et al*, 1979), 15% organic acids (citric, malic and dicarboxylic acids), 8% minerals and 8% peptides and protein as well as traces of monocarboxylic and amino acids,

pigments, polyphenols compounds and vitamins especially vitamin C (Davies and Hobson, 1981). Fuke and Shimizu (1993) stated that glutamic and asparatic acids (the predominant amino acids in tomato fruits) have great effect on tomato taste. Potassium, phosphorus and magnesium salts represented the main minerals of serum in tomato fruit (Salles *et al*, 2003). These salts play an important role on tomato taste ((Petro-Turza, 1987 and Petro-Turza & Teleky-Vamossy, 1989). The concentration of both reducing sugars and organic acids in tomato fruits are markedly affect their flavor (Malundo *et al*, 1995 and Thybo *et al*, 2006). Where reducing sugars for sweet taste and organic acids for sour taste. In this respect, Simandle *et al*, (1996) pointed out tomato taste is significantly correlated with pH and total soluble solids / titratable acidity ratio of its juice. In addition, minerals and free amino acids enhance the taste of tomato products (Stevens, 1985). As a results, technological process of tomato fruits could be altered the percentage of previous compounds and led to change the taste of the final product.

This work was designed to study the changes in the taste-active compounds present in tomato fruits during the technological processing. Therefore, monitoring of sugars, titratable acidity, pH, minerals, free amino acids, peptides and protein concentrations of tomato products (tomato juice and tomato paste) were achieved.

MATERIALS AND METHODS

1. Materials

Rip tomato fruits (Peto 86 variety) were obtained from Horticulture Department, Faculty of Agriculture Tanta University during June 2005. All Chemicals used in this study were of analytical grade.

2. Methods

2.1. Preparation of Tomato Juice

Pre-washed and clean tomato fruits were heated at 85^{0}C for 2 minutes in a water bath. Then fruits were picked up and macerated by mixer (Moulinex, France) at speed no. 2 for 2 minutes (Boehm *et al*, 2003). The macerate was strained through stainless steel screen (0.6 mm). The juice was pasteurized under vacuum at 60^{0}C for 30 minutes (Goose and Binsted, 1973) then filled into 200 ml sterilized glass bottles, closed, cooled rapidly under running tap water and stored at 4^{0}C for further analysis (Fig. A).

2.2. Preparation of Tomato Paste

Non-pasteurized (fresh tomato) juice was concentrated at 65-70^{0}C under vacuum to reach about 25% total solids (El–Kady *et al*, 1982). The paste was filled hot into 300g sterilized glass bottles, capped, cooled rapidly under running tap water and kept at 4^{0}C for further analysis (Fig. A).

2.3. Separation of Serum from Tomato Products

Serum of different tomato products (fresh juice, pasteurized juice and paste) were separated by centrifugation at 4500 – 5000 rpm for 10 min and filtration according to the method of Lamb (1977).

2.4 Analytical Methods

Total solids (TS) and soluble solids (SS) of tomato samples were determined according to the methods of (AOAC, 1990). Glucose and

fructose content of tomato serum were determined using HPLC as outlined by Conrad and Palmer (1976). The conditions used were as follows: column of Aminex HPX-42A (300X7.8 mm) by an elution with isocratic system of acetonirile and water (75:25 v/v) at a flow rate 1.5 ml/min. Identification of glucose and fructose was based on comparison of retention times of the unknown peaks to authentic standards. Total reducing sugars following Lane & Eynon method, ash content, titratable acidity (as citric acid), pH value and total nitrogen (TN) following Kjeldahl procedure of samples were performed as described in AOAC (1990). Non protein nitrogen (NPN) was measured by extracting the samples with 10 % trichloroacetic acid (TCA) according to the method of Naczk *et al.*, (1986). Amino acids content was determined using Beckman Amino Acid Analyzer (Model 194 CL) according to the method of Moore and Stein (1963). Free amino acids were determined according to the method of (Nozal *et al.*, 2004) . Potassium, magnesium, calcium and sodium of tomato serum were measured following the method of Lopez *et al*, (1986) using an Atomic Absorption Spectrophotometer (Perkins–Elmer Instrument, Model 2380). While Phosphorus content was estimated photometrically as described by Chapman and Pratt (1978).

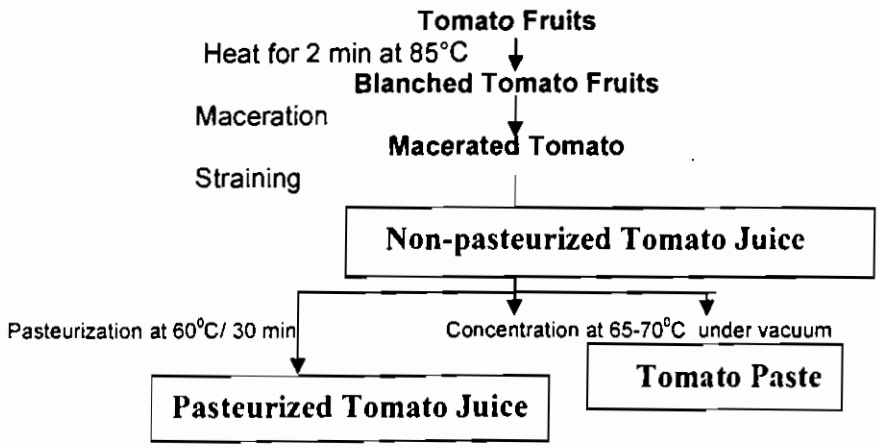

Fig. (A): Diagram for preparing Tomato Products

2.5. Statistical Analysis

Data were statistically analyzed using the Statistical Analysis System software package. Analysis of variance were performed using ANOVA procedures. Significant differences between means were determined using Duncan's multiple range test (Steel and Torrie ,1980) .

RESULTS AND DISCUSSION

Total soluble and insoluble Solids of Tomato Products

Total solid content of non-pasteurized tomato juice was 7.15g /100g increased to 7.53 and 24.76g/100g for pasteurized tomato juice and tomato paste (Table, 1). The corresponding values of soluble solids were 6.04, 6.30 and 22.53 g/l00g for non-pasteurized, pasteurized juices and paste,

respectively. The same trend was found in the insoluble solids content of non-pasteurized (1.11g/100g), pasteurized juices and paste (1.23 g/100g and 2.23 g/100g).

The increment in total and soluble solids of the pasteurized juice rather than non-pasteurized one could be attributed to the effect of heat treatment during pasteurization (Miers *et al*, 1970). While it reached to the maximum in tomato paste due to the concentration process.

Table (1) : Solids content (g/100g fresh weight) of Non- Pasteurized, Pasteurized Tomato Juice and Tomato Paste

Tomato Products	Total solids (M ± SD)	Soluble solids (Serum) (M ± SD)	Insoluble solids (M ± SD)
Non-pasteurized Juice	7.15 ± 0.05[c]	6.04 ± 0.03[c]	1.11 ± 0.07[c]
Pasteurized Juice	7.53 ± 0.06[b]	6.30 ± 0.04[b]	1.23 ± 0.06[b]
Tomato Paste	24. 76 ± 0.13[a]	22.53 ± 0.12[a]	2.23 ± 0.09[a]

In a column means followed by the same letters are not significant different at $p \leq 0.05$
M±SD = mean and standard division

Sugar Content of Tomato Serum Products

Total reducing sugars of tomato serum represented the major constituents of soluble solids. HPLC analysis revealed that main sugar components of tomato serum were glucose and fructose (Table, 2 and Figure, 1). It is clear that glucose and fructose contents of pasteurized juice were higher than those found in non-pasteurized one. Meanwhile, conversion of tomato juice to paste by heating led to pronounced decrease in glucose + fructose and total reducing sugars. This reduction could be attributed to the reaction between reducing sugars and amino acids or organic acids that present in the serum of tomato paste. Furthermore, heat treatment might also induced sugar caramelization (El-Miladi *et al*, 1969).

Titratable Acidity and pH Value of Tomato Serum Products

Acidity of tomato juice affects the taste of tomato fruits and its products. Since suitability of fruits for processing and canning depends in a part on their level of acidity (Soliman, 1989). Results of Table (3) displayed that titratable acidity in the serum of non-pasteutized juice was 7.24mgg^{-1} increased to 7.76mgg^{-1}in the serum of pasteutized one. The highest value (29.00mgg^{-1}) was recorded by tomato serum paste. The augment in titratable acidity of tomato paste could be attributed to the concentration of organic acid of tomato juice during heat processing. These results are in full agreement with Krumbein *et al*, (2004) who reported that titratable acidity of tomato fruits fluctuated between 3.0 to 7.0 mgg^{-1} depending on tomato cultivars.

As for titratable acidity to soluble solids ratio, it is clear that this ratio in non-pasteutized juice was 11.99 g/100g SS increased slightly to 12.22 g/100g SS in pasteurized juice. This could be explained by formation of different organic acids such as acetic and pyrrolidone carboxylic acid which they formed as a result of oxidation of aldehydes and alcohols throughout the thermal processing. While the value failed to 1.29 g/100g SS in tomato paste.

This may be attributed to the high total solids in tomato paste and the lack of reducing sugars in the paste due to reaction between reducing sugars and amino acids as well as sugar caramelization during heat processing (El-Miladi *et al*, 1969)

Table (2): Sugars (Total reducing, Glucose and Fructose) content of tomato serum products (as g sugar / 100g SS*)

Sample	Glucose	Fructose	Glu cose +Fructose	Glucose / Fructose ratio	Total Reducing Sugars (M+SD)
Non-pasteurized Juice	25.82	30.17	55.99	0.86	57.94 ± 2.2 [b]
pasteurized Juice	26.83	31.29	58.12	0.92	60.17 ± 2.1 [a]
Tomato Paste	26.00	28.75	54.75	0.90	55.33 ± 2.3 [c]

In a column, means followed by the same letters are not significant different at p ≤ 0.05
***SS = Soluble Solids**

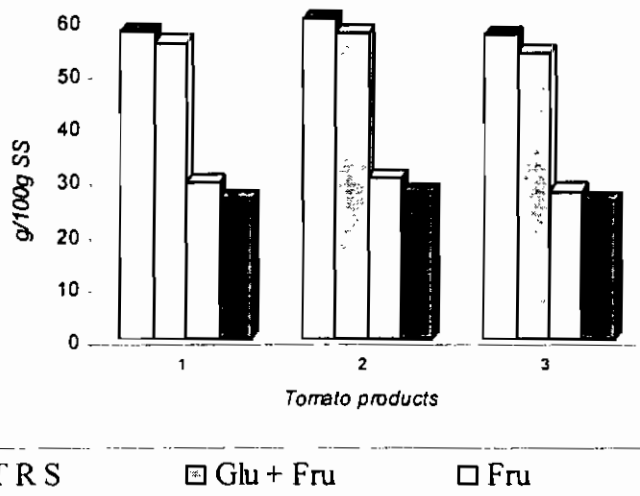

Fig. (1): Glucose Fructose and total reducing sugars content of Tomato and its Products
1-Non-pasteurized tomato juice 2- Pasteurized Tomato juice 3-Tomato paste

Table (3): Titratable Acidity (as citric acid) and pH Value of Fresh Non-Pasteurized, Pasteurized Tomato Juice and Tomato Paste

Tomato Products	Titratable acidity		pH value	✦TRS/ † TA Ratio
	(mg / g FW)*	(g /100 g SS)**		
Non-pasteurized Juice	7.24 ± 0.02 [c]	11.99 ± 0.20 [c]	3.96±0.02	4.83
Pasteurized Juice	7.76 ± 0.03 [b]	12.22 ± 0.15 [b]	3.95±0.03	4.92
Tomato Paste	29.00 ± 0.25 [a]	1.29 ± 0.12 [a]	3.92±0.04	42.89

In a column, means followed by the same letters are not significant different at p ≤ 0.05
*** FW = Fresh weight** **✦ TRS = Total Reducing Sugars**
**** SS = Soluble solids** **† TA = Total Acidity**

It is interesting to note that although the titratable acidity increased during processing, pH value was practically identical. This could be related to the effect of buffering capacity of tomato serum (Gancedo and Luh, 1986). The ratio of total reducing sugars to titratable acidity as citric acid was 4.83 for non-pasteurized juice increased to 4.92 in the pasteurized one. The highest ratio (42.89) was found in tomato paste. Malundo *et al*, (1995) stated that the ratio between sugar content and acidity has a significant effect on the fruit taste. This ratio altered at the time of ripening or during fruits processing.

Minerals and Ash Contents of Tomato serum Products

Minerals content of tomato fruits, especially potassium and phosphorus, play an important role in tomato taste, flavor, acidity and nutritional values (Stevens, 1985). As shown in Table (4) potassium and phosphorus were the predominant elements in tomato serum of non-pasteurized juice followed by magnesium and calcium. The lowest limiting mineral in the serum of non-pasteurized juice was sodium. The concentration of these minerals were slightly increase due to heat treatment whereby serum of both pasteurized juice and paste contained higher amounts of minerals comparing with that of non-pasteurized juice. Such results were reported by Ammar *et al*, (1982). Likewise, tomato serum achieved from non-pasteurized juice involved lower amounts of ash than those detected in tomato pasteurized juice and paste. These results are in the line of El-Kady *et al*,(1982).

Table (4): Mineral and ash contents (g /100g SS*) in serum of of Fresh Non-Pasteurized, Pasteurized Tomato Juice and Tomato Paste

Tomato Products	K	Mg	Ca	Na	P	Total mineral	Ash
Non-pasteurized Juice	4.81	0.32	0.17	0.07	0.59	5.96	09.60 ± 0.35 [c]
Pasteurized Juice	4.82	0.33	0.18	0.08	0.60	6.01	10.03 ± 0.31 [b]
Tomato Paste	4.83	0.34	0.19	0.09	0.62	6.05	11.20 ± 0.40 [a]

In a column, means followed by the same letters are not significant different at $p \leq 0.05$
*** SS = Soluble Solids**

Distribution of Nitrogenous Compounds in Tomato Products

Data in Table (5) indicate that total nitrogen and crude protein contents (as g/100g TS) of non-pasteurized juice were 2.51 and 15.69, respectively. These results are conflicted with those reported before (Paul and Southgate 1978; El-Nemr *et al*,1995). The variations in total nitrogen content may be related to the diversity of tomato genotype and agriculture conditions (Flores *et al.*, 2003).

However, total nitrogen of tomato products was gradually decreased due to heat treatment. In the respect of soluble nitrogen content in the tomato serum, it was clear that total nitrogen content of non-pasteurized tomato juice was 2.08 which represent 82.87% of total nitrogen decreased to 2.06 and 1.90 g/100g SS. which represent 85.12% and 91.35% of total nitrogen in pasteurized tomato juice and paste, respectively. As a result, non - protein nitrogen and protein nitrogen contents of non-pasteurized tomato juice (0.78

and 1.30 g/100g SS) decreased gradually to reach the minimum (0.71 and 1.19 g/100g SS) in the tomato paste.

Table (5): Distribution of nitrogenous compounds in tomato products. (g/100g)

Nitrogenous Compounds	Non-pasteurized Juice			Pasteurized Juice			Paste		
	Whole (M±SD)	Serum (M±SD)	Residue (M±SD)	Whole (M±SD)	Serum (M±SD)	Residue (M±SD)	Whole (M±SD)	Serum (M±SD)	Residue (M±SD)
TN*	2.51±0.10 (100%)	2.08±0.05 (82.87%)	0.43±0.02 (17.13%)	2.42±0.10 (100%)	2.06±0.14 (85.12%)	0.36±0.02 (14.88%)	2.08±0.05 (100%)	1.90±0.04 (91.35%)	0.18±0.01 (8.65%)
NPN**		0.78±.03			0.79±0.03			0.71±0.02	
PN***		1.30±0.07			1.27±0.06			1.19±0.03	
% Crude Protein	15.69 ±0.11	13.00 ±0.07	2.69 ±0.02	15.13 ±0.10	12.88 ±0.14	2.25 ±0.02	13.00 ±0.05	11.88 ±0.04	1.13 ±0.01

M±SD= Mean ± Standard deviation
TN* = Total nitrogen
NPN = Non-protein nitrogen**
PN* = Protein nitrogen**
Crude protein = TN × 6.25

Amino Acids Composition and Free Amino Acids Content in Serum of Tomato Products

Quantitative analysis of the free amino acids in non-pasteurized and pasteurized tomato juice and tomato paste were presented in Table (6). It is obvious that, glutamic, glutamine, γ- amino butyric, asparatic, alanine and threonine were the predominant free amino acid in the serum of non-pasteurized tomato juice. While the other individual free amino acids were found in concentration less than 5% of total free acids. These results are in agreement with Boggio *et al*, (2000) Who mentioned that main free amino acid in tomato fruit are glutamate and asparatic. It is interesting to note that total free amino acid content in the serum of pasteurized tomato juice (877.97 mg/100g) and past (2241.99mg/100g) were higher than that of the serum of non-pasteurized tomato juice (849.95mg/100g) based on fresh weight. However, their ratio to soluble solids (SS) were lower than that of non-pasteurized tomato juice. Whereas, free amino acid content of serum in non-pasteurized tomato juice related to soluble solids was 14.08mg/100g SS decreased to 13.87mg/100g SS and 9.95mg/100g SS in the serum of pasteurized tomato juice and paste, respectively. Such results were noticed by El-Miladi *et al*, (1969) who showed that processing resulted in a substantial increase the free amino acids content of fresh tomato fruits as a result of protein denaturation and partial hydrolysis.

As shown in Table (7) non-pasteurized tomato juice and its products are free from asparagines and glutamine. In contrast they are a good source for glutamic, γ – amino butyric and asparatic. The predominant essential amino acid are threonine, lysine and phenylalanine. Processing of tomato fruits led to slightly increase in the amino acid content in the final products (Pasteurized juice and tomato past).

Table (6): Free Amino Acids Content of Serum Fresh Non-pasteurized, Pasteurized Tomato Juices and Tomato Paste

Amino acid	Non-Pasteurized Juice		Pasteurized Juice		Tomato Paste	
	mg/100g FW*	g/100g SS**	mg/100g FW*	g/100g SS**	mg/100g FW*	g/100g SS**
Leucine	6.39	0.106	7.32	0.116	9.39	0.042
Lysine	14.12	0.234	14.69	0.233	24.48	0.109
Methionine	2.33	0.039	2.54	0.040	3.49	0.016
Phenylalanine	16.70	0.277	17.29	0.275	47.16	0.209
Threonine	44.17	0.731	46.12	0.733	167.48	0.744
Valine	8.76	0.145	9.17	0.146	7.01	0.031
Arginine	7.15	0.118	8.09	0.128	16.54	0.074
Histidine	10.73	0.178	11.47	0.182	24.79	0.110
Alanine	59.88	0.992	63.56	1.009	20.38	0.091
Asparagine	35.61	0.590	36.36	0.577	104.51	0.464
Asparatic	67.26	1.114	68.12	1.081	278.73	1.237
Cysteine	0.58	0.010	0.83	0.013	0.50	0.002
Glutamine	160.83	2.663	162.08	2.573	78.40	0.348
Glycine	3.22	0.053	3.81	0.061	3.54	0.016
Glutamic	270.38	4.477	279.62	4.438	1006.64	4.468
Isoleucine	7.30	0.121	8.33	0.132	9.83	0.044
γ-amino butyric	111.43	1.845	112.02	1.778	378.08	1.678
Serine	14.04	0.233	14.89	0.237	43.93	0.195
Tyrosine	9.07	0.150	11.66	0.115	17.11	0.076
Total	849.95	14.08	877.97	13.87	2241.99	9.95

* FW = Fresh weight ** SS = Soluble solids

Amino acids in bold-faced are essential amino acids as mentioned by Sanders and Amery (2003)

Table (7) : Amino Acids Composition of Serum Fresh Non- pasteurized, Pasteurized Tomato Juices and Tomato Taste

Amino acid	Non-pasteurized Juice		Pasteurized Juice		Tomato Paste	
	mg/100g FW*	g/100g SS**	mg/100g FW*	g/100g SS**	mg/100g FW*	g/100g SS**
Leucine	6.57	0.109	6.67	0.106	34.08	0.151
Lysine	12.55	0.208	13.49	0.214	42.52	0.189
Methionine	0.79	0.013	0.95	0.015	5.29	0.024
Phenylalaninene	10.23	0.170	10.47	0.166	62.86	0.279
Threonine	15.30	0.254	17.02	0.270	45.95	0.204
Valine	7.34	0.122	8.17	0.130	25.19	0.112
Arginine	6.31	0.105	6.53	0.104	26.59	0.118
Histidine	7.55	0.125	7.88	0.125	20.49	0.091
Alanine	20.57	0.341	22.35	0.355	38.29	0.170
Asparagine	-	-	-	-	-	-
Aspartic	133.57	2.211	143.74	2.282	477.00	2.117
Cysteine	2.13	0.035	2.32	0.037	2.91	0.013
Glutamine	-	-	-	-	-	-
Glutamic	966.53	16.002	998.55	15.850	3373.65	14.974
Glycine	6.97	0.116	7.88	0.125	32.59	0.145
Isoleucine	5.52	0.092	7.30	0.116	21.53	0.096
γ-amino butyric	138.29	2.290	145.73	2.313	246.46	1.094
Serine	15.25	0.253	16.15	0.257	44.76	0.199
Tyrosine	5.44	0.090	6.61	0.105	22.29	0.099
Total	1360.91	22.54	1421.81	22.57	4531.85	20.66

* FW = Fresh weight ** SS = Soluble solids

Amino acids in bold-faced are essential amino acids as mentioned by Sanders and Amery (2003)

Data of Table (8) display that free amino acids and peptide contents of non-pasteurized tomato juice were 14.08 and 8.46g /100g SS, respectively. The corresponding values for pasteurized tomato juice were 13.87 g/100g SS and 8.70 g/100g SS, respectively. The ratio of free amino acids to peptides was approximate 1.7 for non-pasteurized tomato juice, decreased to 1.6 and 1.00 for the pasteurized juice and paste, respectively. However, the amount of free amino acids in tomato paste decreased comparing with pasteurized and non-pasteurized tomato juice.

Table (8):Free Amino Acids and Peptides Contents (g / 100g SS) of Non-pasteurized, Pasteurized Tomato Juice and Tomato Paste

Tomato Products	Total Amino Acids (TAA)	Free Amino Acids (FAA)	*Peptides content(Pep)	FAA/Pep Ratio
Non-pasteurized Juice	22.54	14.08	8.46	1.7
Pasteurized Juice	22.57	13.87	8.70	1.6
Tomato Paste	20.06	9.95	10.10	1.0

*Peptides content = total amino acids content - free amino acids content

In conclusion main components in the serum of non-pasteurized tomato juice were reducing sugars. Glucose and fructose were present in a ratio about 1:1. Titratable acidity of non-pasteurized juice was 11.99 mg /100g SS as citric acid. Potassium (4.81mg/100gSS); phosphorus (0.59mg/100g SS) and magnesium (0.32mg/100g SS) were the major minerals. The total amount of free amino acids and peptides were 14.08g/100g SS and 8.46 g/100g SS which consider taste-active compounds in tomato juice. The total nitrogen and crude protein contents were 2.51 and 15.69 g/100g in non- pasteurized juice. These constitutes were gradually changed during processing. So, taste of non- pasteurized tomato juice altered.

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