Some Quality Attributes of Some Tomato Concentrate Brands Produced In Egypt and Yemen

El-Sanabani, A. S., A. A. Shatta, Kh. M. Youssef and S. K. El-Samahy
Food Technol. Dept., Fac. of Agric., Suez Canal Univ., 41522 Ismailia, Egypt.

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Abstract: The present study deals with some quality attributes of the tomato concentrate (paste or puree) marketed in Egypt and Yemen under different brands. The impetus behind the present study was the numerous beneficial effects that could be gained from tomato concentrate (paste or puree). The whole work was conducted according to the Egyptian and Yemeni standards. The results of chemical and microbiological determinations showed some or great variations between the tested Egyptian and Yemeni tomato concentrate brands. Therefore, serious control on the quality of tomato concentrate is required. There were a well positive correlations between rheological properties especially, apparent viscosity and total pectin contents. There was a good correlations between Hunter color readings and a^*/b^* ratio of the samples and concentrations of lycopene and total carotenoids. The effect of temperature on viscosity was very well correlated with the Arrhenius equation ($R^2 > 0.90$).

Keywords: Tomato concentrate, Egyptian and Yemeni standards, chemical composition, rheological properties, quality control, color, lycopene, carotenoids, pectin.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the world's major food crops and the second most consumed vegetable in the world (Gould, 1992 and Willcox *et al.*, 2003). Tomatoes are used either fresh or as a range of processed products (tomato juice, tomato puree, tomato paste, etc). Tomato puree and paste may be marketed directly to the consumer or it may be an ingredient in other products i.e. ketchup, soup and sauces (Hayes *et al.*, 1998 and Mazaheri-Tehrani and Ghandi, 2007). Consequently, tomatoes and tomato products may provide a convenient matrix by which nutrients and other health related food components can be supplied to human at comparatively low prices than other vegetables. Moreover, the regular consumption of tomato and tomato products has been correlated with a reduced risk of various cancers and cardiovascular diseases (LeMarchand *et al.*, 1989; Franceschi *et al.*, 1994; Giovannucci, 1999; 2002; Willcox *et al.*, 2003; Sesso *et al.*, 2004 and Walfisch *et al.*, 2007).

The annul production of tomatoes in the world is about 129.6 million tons (FAO, 2009). Over 7.5 million tons of tomatoes are produced annually in Egypt. Whereas the annual production of tomatoes in Yemen is 239,897 tons (FAO, 2009). In Egypt, a small portion of this sum is processed (~1%) into paste (Shatta, 2000). But in USA, more than 80% of the tomato annual consumption is consumed in the form of processed products (Willcox *et al.*, 2003).

Tomato paste is a dispersion of solid particles (pulp) in an aqueous medium (serum) resulting from the concentration of tomato juice after the removal of skin and seeds and contains 24% or more natural tomato soluble solids (NTSS) (Gould, 1992 and Hayes *et al.*, 1998). While, tomato puree contains 8% to less than 24% NTSS.

The principal quality parameters of tomato paste are color, consistency, flavor, in addition to compositional standards. Several characteristics such as soluble solids, acidity and pH are essential quality parameters for processed tomatoes. Also, tomato pastes must have intrinic rheological characteristics which make them suitable for the various processing applications (Hayes *et al.*, 1998; Rodrigo *et al.*, 2007 and Hsu, 2008).

A problem that has not been resolved and that has been the main cause of disputes among companies dealing with tomato products is the absence of world-wide standards to define tomato paste quality and composition (Porretta *et al.*, 1992) and there are considerable differences among the standards that are currently in use.

The present work aims to evaluate the quality of some tomato concentrate (paste or puree) brands collected from local markets in Egypt and Yemen regarding some of the regulatory quality standards.

MATERIALS AND METHODS

Ten tomato concentrates (paste or puree) brands were purchased from local markets, five from Ismailia Governorate, Egypt namely: El-Rashidi, Fine Foods, Foodico, Heinz and Royal; and five from Dhamar and Sanaa Governorate, Yemen namely: Abou-Torbosh, Al-Ghadeer, Al-Jawhara, Bajil and Seven Star. The samples were tested directly after their packages had been opened. Table (1) listed some information about these samples.

Chemical analyses:

Moisture content, total soluble solids (TSS, °Brix), pH value, titratable acidity (%, as citric acid), salt content (%, NaCl) and total pectins (water soluble, ammonium oxalate 0.2% and 0.05*N* HCl fractions) were determined according to the AOAC (2002). Carotenoids and chlorophyll were assayed and calculated according to Wettestein (1957), lycopene content (mg $100g^{-1}$ paste) was determined according to Ranganna (1977) The free-salt Brix was calculated by subtracting the salt percent from the degree of Brix reading by refractometer.

Table (1): A list of surveyed tomato concentrate (paste or puree) samples collected from Egypt and Yemen

Brand	Ingredient and type of pack	Market
Egyptian Samples		
El-Rashidi	Tomato paste (20-22%), salt 2%, packed in a glass jar	Ismailia
Fine Foods	Heavy concentration puree (22%), salt 2%, packed in an aluminium foil bag	Ismailia
Foodico	Heavy concentration puree (22%), salt 3%, packed in a glass jar	Ismailia
Heinz	Tomato sauce (22%), salt, packed in a carton box	Ismailia
Royal	Tomato sauce (20-22%), salt, 2%, packed in a glass jar	Ismailia
Yemeni Samples		
Abou-Torbosh	Tomato paste (22%), salt 2%; packed in a carton box	Sanaa
Al-Ghadeer	Tomato paste (18%), salt 2%; packed in an aluminium foil bag	Dhamar
Al-Jawhara	Tomato paste (18-20%), salt 2%; packed in a polyethylene bag	Sanaa
Bajil	Tomato paste (22-24%), salt 2%, packed in a glass jar	Dhamar
Seven-Star	Tomato pulp (20-22%), salt 2%; packed in a tin can	Sanaa

Physical measurements and Howard mould count:

The color attributes of tomato concentrate samples were measured (as described by Gomez *et al.*, 1998) in a cylindrical sample cup (5 cm diameter × 2 cm height) filled to the top with the sample using a LabScan E16114 (Hunter Associates Laboratory, Reston, VA, USA). Standard color plate No. 400 with reflectance values L^*= 25.70, a^*= 33.60 and b^*= 14.70 was used as a reference. The tomato concentrate (paste or puree) samples were diluted to 12 °Brix before measuring. The red–yellow (a^*/b^*) ratio was recorded to indicate the redness of the tomato concentrate samples (Min and Zhang, 2003).

Consistency was measured by Bostwick consistometer (SC Scientific, USA) within 30 seconds at 12 °Brix as described by Gould (1992). The black specks were determined according the same author.

The Howard mould count was determined according to AOAC (2002).

Rheological measurements and activation energy calculation:

Rheological properties of tomato concentrates (paste or puree) were determined using Brookfield digital rheometer model DV-III$^+$ (Brookfield Engineering Lab., INC., Middleboro, USA) at 20 °C. The Brookfield small sample adaptor and Sc_{4-14} spindle were used. The data were analyzed using the Casson [Eq. 1] and power law [Eq. 2] mathematical models (Hegedusic *et al.*, 1995). These models are:

$$(\tau)^{0.5} = (\tau_o)^{0.5} + (\eta\gamma)^{0.5} \quad \textbf{[Eq. 1]},$$

$$\tau = K\gamma^n \quad \textbf{[Eq. 2]}$$

where, τ= shear stress (Nm^{-2}), τ_o= yield stress (Nm^{-2}), η= plastic viscosity (mPa s), γ= shear rate (s^{-1}), k= consistency coefficient (mPa s^n), n= flow behavior index (dimensionless). The apparent viscosity (mPa s) was measured at 10 rpm at 20 °C.

Activation energy was calculated using Arrhenius type equation as mentioned by Ibarz *et al.* (1996a):

$$\eta = \eta_\infty \, e^{(Ea/RT)} \quad \textbf{[Eq. 3]},$$

where, η is the viscosity, η_∞ is a constant, E_a is the activation energy of flow, R is the gas constant and T is the absolute temperature in °K.

Statistical analysis:

Analysis of variance (ANOVA) was performed using CoStat under windows program (CoStat program ver. 6.311, 2005). Duncan's multiple range test was used to establish the multiple comparisons of the mean values at p= 0.05.

RESULTS AND DISCUSSION

Some quality attributes of some commercial Egyptian and Yemeni tomato concentrate:

Total soluble solids (TSS) content is the most important quality criteria for tomato paste. According to the Food and Drug Administration (FDA) tomato paste is strained tomatoes concentrated by evaporation with or without the addition of salt and contains not less than 24% salt free tomato solids (Luh and Kean, 1998). Also, according to the FDA and USDA standards, tomato pastes are divided into three types: heavy, medium and light. Heavy tomato pastes contain not less than 33% of salt free tomato solids. Pastes of medium concentration contain from 28 to 33% of salt free tomato solids and light pastes 24 to 28% (Hayes *et al.*, 1998; Luh and Kean, 1998). Moreover, Hayes *et al.* (1998) reported that USDA standards divided tomato purees into four types according to the natural tomato soluble solids percent: extra heavy (15.0 to ≤ 24.0%), heavy (11.3 to ≤ 15.0%), medium (10.2 to ≤ 11.3%) and light (8.0 to ≤ 10.2%).

The Codex standards for processed tomato concentrates and Yemeni standards (2006) are different, with seven grades defined in relation to minimum tomato content. The Codex standards also defines tomato puree as containing not less than 8% but not more than 24% NTSS and tomato paste as containing at least 24% NTSS (Kirk and Sawyer, 1991). Also, the Egyptian standards (2005) defined tomato puree as containing not less than 8% and not more than 24%; tomato paste, concentrated tomato puree (tomato sauce) as containing from 18 to 24% NTSS.

Table (2): Some quality attributes of some commercial Egyptian and Yemeni tomato concentrate (paste or puree) samples

Quality attribute	Egyptian samples					Yemeni samples				
	EL Rashidi	Fine Foods	Foodico	Heinz	Royal	Abou Torbosh	Al Ghadeer	Al Jawhara	Bajil	Seven Star
Moisture content	78.20^{d}	75.80^{f}	71.50^{h}	74.00^{g}	78.30^{d}	73.40^{g}	81.60^{b}	83.30^{a}	76.90^{e}	79.20^{c}
TSS (°Brix)	19.80^{f}	22.20^{d}	26.50^{a}	24.00^{b}	19.10^{g}	23.50^{c}	16.30^{h}	14.70^{i}	21.20^{e}	19.30^{g}
Salt (%, NaCl)	1.80^{b}	2.00^{a}	2.00^{a}	2.00^{a}	2.00^{a}	1.50^{c}	2.00^{a}	1.70^{b}	1.75^{b}	1.80^{b}
Salt free Brix	18.00^{e}	20.20^{c}	24.50^{a}	22.00^{b}	17.10^{g}	22.00^{b}	14.30^{h}	13.00^{i}	19.45^{d}	17.50^{f}
pH value	4.21^{ab}	4.22^{ab}	4.25^{a}	4.12^{bc}	4.20^{ab}	4.03^{c}	3.90^{e}	4.01^{cde}	4.00^{de}	4.17^{ab}
Titratable acidity (%, as citric acid)	1.95^{cd}	1.99^{bc}	1.81^{g}	2.04^{a}	1.90^{ef}	1.93^{de}	2.02^{ab}	2.01^{ab}	1.90^{ef}	1.88^{f}
Acidity/ °Brix (%)	9.85^{c}	8.96^{d}	6.83^{f}	10.00^{c}	9.95^{c}	8.21^{e}	12.39^{b}	13.67^{a}	8.96^{d}	9.74^{c}
Howard mould count (%, positive fields)	54.00^{b}	26.00^{c}	9.00^{g}	22.00^{d}	61.00^{a}	6.00^{h}	15.00^{f}	19.00^{e}	20.00^{de}	21.00^{de}

Means of triplicates
Means having the same letter within each row are not significantly different at $p= 0.05$

Table (3): Pigments content (mg 100g^{-1}), color attributes and black specks of some commercial Egyptian and Yemeni tomato concentrate (paste or puree) samples

Item	Egyptian samples					Yemeni samples				
	EL Rashidi	Fine Foods	Foodico	Heinz	Royal	Abou Torbosh	Al Ghadeer	Al Jawhara	Bajil	Seven Star
Total carotenoids	3.11^{d}	3.05^{d}	3.54^{b}	3.21^{c}	3.26^{c}	2.93^{e}	2.15^{g}	2.83^{f}	3.71^{a}	2.82^{f}
Chlorophyll a	1.60^{a}	1.36^{c}	1.08^{de}	0.86^{f}	0.81^{f}	0.99^{e}	1.15^{d}	0.63^{g}	1.37^{c}	1.50^{b}
Chlorophyll b	3.26^{b}	2.94^{d}	2.65^{e}	1.88^{g}	1.67^{i}	2.21^{f}	3.10^{c}	1.78^{h}	3.27^{b}	3.73^{a}
Lycopene	3.635^{c}	3.713^{b}	3.744^{ab}	3.757^{ab}	3.635^{c}	3.629^{c}	3.201^{d}	3.688^{bc}	3.784^{a}	3.629^{c}
Color attributes										
L^*	21.80^{c}	23.43^{ab}	23.30^{ab}	23.07^{b}	23.00^{b}	21.47^{c}	19.05^{d}	21.63^{c}	24.14^{a}	21.07^{c}
a^*	19.75^{d}	22.05^{bc}	26.41^{a}	23.71^{b}	20.10^{cd}	20.78^{bcd}	11.55^{e}	20.65^{cd}	28.00^{a}	20.68^{cd}
b^*	12.45^{c}	13.42^{b}	13.60^{b}	13.24^{b}	12.59^{c}	12.54^{c}	10.30^{d}	12.30^{c}	14.03^{a}	12.40^{c}
a^*/b^*	1.59^{c}	1.64^{bc}	1.94^{a}	1.78^{bc}	1.60^{c}	1.66^{bc}	1.12^{d}	1.68^{bc}	2.00^{a}	1.67^{bc}
Black specks										
More than 1.5mm	0.00^{d}	0.00^{d}	0.00^{d}	0.00^{d}	7.00^{a}	0.00^{d}	5.00^{b}	2.00^{c}	0.00^{d}	0.00^{d}
Between 1.0 - 1.5mm	3.00^{bcd}	2.00^{cd}	2.00^{cd}	2.00^{cd}	4.00^{bc}	2.00^{cd}	7.00^{a}	5.00^{ab}	1.00^{d}	2.00^{cd}
Less than 1.0mm	4.00^{cd}	3.00^{cd}	4.00^{cd}	3.00^{cd}	9.00^{b}	5.00^{c}	30.00^{a}	10.00^{b}	2.00^{d}	2.00^{d}

Means of triplicates
Means having the same letter within each row are not significantly different at $p= 0.05$
L^* = lightness, 0 = black, 100 = white; + a^* = red, -a^* = green; +b^* = yellow, -b^* = blue

The results presented in Table (2) indicated that, the total soluble solids (TSS, °Brix) of tomato concentrates (paste or puree) varied from 14.70 (Al-Jawhara, Yemeni brand) to 26.50 (Foodico, Egyptian brand) and there was a significant difference among the samples under investigation. However, in the FDA, USDA, Egyptian and Yemeni standards the "salt free Brix" is regarded as a standard criterion for tomato concentrate (paste or puree) (Farahnaky *et al.*, 2010). The salt free Brix of the tomato concentrates ranged from 13.0 (Al-Jawhara, Yemen) to 24.5% (Foodico, Egypt) and most of samples were in the range of 14.3-22.0% (Table, 2). According to the Egyptian (2005) and Yemeni (2006) standards, the natural tomato soluble solids should range from 24.0 to 36.0% for paste and 8.0 to ≤ 24.0% for puree. Most of the Egyptian and Yemeni tomato concentrate samples were extra heavy concentrated puree. While, Al-Jawhara and Al-Ghadeer brands (Yemen) were heavy concentrated puree, only one sample (Foodico, Egyptian brand) was light tomato paste. The differences in the °Brix of the samples indicated high variations in terms of process conditions and the raw materials used.

Because of the concerns over health related issues regarding high intake of salt by the consumers, the level of salt in different foods has become the focus in many researches. The salt content of the samples significantly differed and ranged from 1.5 to 2.0% (in all cases). According to the standards, the maximum salt content of tomato concentrate is 2.0% (W/W) (Farahnaky and Hill, 2007).

The pH values of the tomato concentrate samples were in the range of 4.12 - 4.25 (Egyptian brands) to 3.90 - 4.17 (Yemeni brands) and there were significant differences among the samples. The maximum pH value of tomato concentrate is 4.5 in Egyptian standards and is 4.4 in Yemeni standards. Since tomato pastes or purees are pasteurized and not sterilized, low pH is an important factor for microbial stability, i.e. preventing the growth of pathogenic microorganisms. The obtained results (Table, 2) were within the range of both Egyptian and Yemeni standards specifications. Also, titratable acidity (%, as citric acid) values were within the range of Yemeni standards (1.8 - 2.2%). Thus, they ranged between 1.81 and 2.04% (Egyptian brands) and 1.88 - 2.02% (Yemeni brands).

The titratable acidity and total soluble solids are the main components responsible for tomato flavor (Kader, 1986). Also, acidity/°Brix percent is an important factor which indicates the sweetness or sourness of the product (Jha and Matsuoka, 2004). The Yemeni standards mentioned that the ratio of 9.5 is a maximum. The Egyptian samples ranged between 6.83 and 10.0 and Yemeni samples between 8.21 and 13.67. The Fine Foods, Foodico (from Egypt), Abou-Torbosh and Bajil (from Yemen) brands lied within the range specified by Yemeni standards (max. 9.5). The rest of brands were out of Yemeni standards (2006).

Regarding the Howard mould count, data in Table (2) showed that, most of Egyptian and Yemeni samples lied within the values specified by the both standards (max. 50%). The Howard mould counts which present the percentage of the fields found positive, ranged between 6 (Abou-Torbosh, Yemen) and 26% (Fine Foods, Egypt). Only two samples were out of the standards, namely El- Rashidi and Royal brands (from Egypt), where the count percents were 54 and 61%, respectively. If weather conditions are unfavorable prior to or during harvest, mould levels can increase, and thereby adversely affect quality and potentially exceed regulatory limits (Hayes *et al.*, 1998). The presence of an important mould count in the tomato concentrate testifies a use of raw materials of bad quality (Gould, 1983).

The pigments content, color attributes and black specks of some commercial Egyptian and Yemeni tomato concentrate samples:

Color becomes the most important quality attributes for tomato industry. Carotenoids and chlorophyll are responsible for the color of tomatoes. There are two main carotenoids in the tomato, lycopene which is the major carotenoid that imparts the red color of the tomato and β-carotene (Arias *et al.*, 2000). The results in Table (3) showed that, the total carotenoids content (mg $100g^{-1}$) ranged between 3.05 and 3.54 for the Egyptian brands and 2.15 - 3.71 for the Yemeni brands. There were significant differences among the samples in chlorophyll *a* and *b* contents. Lycopene content (mg $100g^{-1}$) ranged between 3.201 and 3.784 (in all cases).

Lightness (L^*) and a^*/b^* ratio (being an indicative quality parameter for the color of tomato products) of the samples were measured to qualify the extent of the color differences between tomato concentrate (paste or puree) samples. The L^* values of the samples ranged between 19.05 (Al-Ghadeer, Yemen) and 24.14 (Bajil, Yemen). There were also differences between the tomato concentrate samples in terms of a^*/b^* ratio which varied from 1.12 - 2.00. According to Goose and Binstead (1973), D'Souza *et al.* (1992) and Arias *et al.* (2000), a^*/b^* ratio of 1.90 or higher represents a top quality product in terms of color, while ratio of less than 1.80 indicates that the tomato paste or puree may be unacceptable. A low a^*/b^* ratio (orange to brown color) is a result of the degradation of lycopene and formation of Maillard reaction products by the intensive heat treatment (Krebbers *et al.*, 2003). The results in Table (3) showed that, the minimum requirements for quality product were not met; for most of the brands with the proposed standards. Only, two brands (Bajil from Yemen and Foodico from Egypt) lied within the specified value (1.90).

Tomato pigments have been correlated with Hunter color readings. The L^*, a^* and b^* values were correlated with the lycopene content. The L^* factor was the best correlated parameter (R^2= 0.94, Watada *et al.*, 1976 and R^2= 0.962, Youssef, 2009). D'Souza *et al.* (1992) found that, the best correlation between lycopene and color (R^2= 0.83) was with the $(a^*/b^*)^2$ factor. The results in Table (4) summarized the linear and exponential regressions (R^2) of the color readings with the lycopene and total carotenoids contents. The relations between color readings and lycopene content can be described as an exponential rise (R^2= 0.80 - 0.94), the best correlation between lycopene and color (R^2= 0.94) was with a^* factor. Also, the linear regression of color readings and lycopene produced was a fair fit (R^2= 0.78 - 0.89). These results are in agreement with those obtained by Arias *et al.* (2000). In the case of carotenoids, both linear and exponential correlations with color readings were similar. Figures (1 and 2) showed the exponential rise of lycopene and carotenoids contents with color readings and the following equations showed the lycopene and carotenoids logarithmic functions and their linear correlations:

Lycopene (mg $100g^{-1}$) = $0.1255\,L^* + 0.856$
Lycopene (mg $100g^{-1}$) = $2.661\ \ln(L^* - 5.6408)$
Lycopene (mg $100g^{-1}$) = $0.04\,a^* + 2.781$
Lycopene (mg $100g^{-1}$) = $0.711\ \ln(a^* - 0.125)$
Lycopene (mg $100g^{-1}$) = $0.170\,b^* + 1.479$
Lycopene (mg $100g^{-1}$) = $2.026\ \ln(b^* - 2.0951)$
Lycopene (mg $100g^{-1}$) = $0.747\,(a^*/b^*) + 2.395$
Lycopene (mg $100g^{-1}$) = $1.097\ \ln[(a^*/b^*) - 0.0598]$
Carotenoids (mg $100g^{-1}$) = $0.309\,L^* - 3.804$
Carotenoids (mg $100g^{-1}$) = $6.662\ \ln(L^* - 13.989)$
Carotenoids (mg $100g^{-1}$) = $0.104\,a^* + 0.837$
Carotenoids (mg $100g^{-1}$) = $1.955\ \ln(a^* - 4.3627)$
Carotenoids (mg $100g^{-1}$) = $0.452\,b^* - 2.670$
Carotenoids (mg $100g^{-1}$) = $5.470\ \ln(b^* - 7.226)$
Carotenoids (mg $100g^{-1}$) = $2.0\,(a^*/b^*) + 0.26$
Carotenoids (mg $100g^{-1}$) = $3.03\ \ln[(a^*/b^*) - 0.60]$

Regarding the black specks, they were classified as small (0.5 to 1.0 mm), medium (1.0 to 1.5 mm) and large (>1.5 mm). The presence of any large specks indicates severe thermal abuse of the product during processing (Hayes *et al.*, 1998). The Egyptian standards classified the black specks into small <0.3 mm, medium 0.3-1.0 and large >1.0 mm, while Yemeni standards mentioned nothing. Black specks in six tomato concentrate brands (Table 3) were in the range of all the specifications of the Egyptian standards. Royal and El-Rashidi brands (from Egypt) and Al-Jawhara and Al-Ghadeer brands (from Yemen) were out of some of the world and Egyptian standards.

Pectin fractions content, consistency and rheological properties of some commercial Egyptian and Yemeni tomato concentrate samples:

Data in Table (5) showed the total and pectin fractions contents. There were significant differences among all samples.

Consistency of tomato products (i.e. paste) refers to their viscosity and the ability of their solid portion to remain in suspension throughout the shelf-life of the product. It is strongly affected by the composition of the pectins. Controlling the breakdown or retention of the pectins is of great importance during processing (Hayes *et al.*, 1998). The consistency of the collected samples measured by Bostwick ranged between 8.0 and 11.5 cm. According to the Egyptian and Yemeni standards, the Bostwick value (cm) ranged between 8.0 and 12.0 and 5.0 and 9.0, respectively. The Egyptian samples fell within the range specified by the Egyptian standards. But, Yemeni samples were out of Yemeni standards, except Al-Jawhara and Bajil brands (Table, 5). Luh *et al.* (1954) reported that consistency was found to be related to pectic substances and total solids contents. York *et al.* (1967) suggested a linear correlation between the water insoluble solids content of tomato paste and the Bostwick consistency in spite of the small differences in magnitude of these constituents.

Figure (3) showed no high correlation between Bostwick consistency and total pectin fractions content, except with acid soluble pectin fraction (linear regression R^2= 0.34). This indicated that probably other compositional factors were also involved in the correlation (Marsh *et al.*, 1980).

Regarding the rheological properties of the commercial tomato concentrate samples, there were significant differences among samples in all studied properties. As the viscosity is depending upon the intermolecular distances and when the TSS increase the intermolecular distances decrease, it was normally to observe an increment in the plastic viscosity and/ or apparent viscosity at 10 rpm (mPa s). Thus the highest values of plastic viscosity (1372.0 mPa s) and apparent viscosity (46064 mPa s) were for Foodico brand sample from Egypt (26.5 °Brix), while the lowest values (63.5 and 5392 mPa s, respectively) were for Al-Jawhara brand sample from Yemen (14.7 °Brix). The same observation was found with consistency coefficient values. They ranged between 1678.0 mPa s^n for Al-Jawhara brand sample and 19258 mPa s^n for Foodico brand sample (Table, 5). The consistency values for the rest samples were in between. The flow behavior index (n) values for the samples ranged between 0.08 and 0.25, less than one, meaning that the samples had a shear thinning behavior (pseudoplastic). Several researchers have shown that difficulties in quality control arise from the great variation in flow behavior in commercial tomato paste caused by different agronomical and processing conditions (Lorenzo *et al.*, 1997; Sánchez *et al.*, 2002 and Thybo *et al.*, 2005).

Pectin significantly influences the textural and rheological properties of tomato products, because of its great thickening and gel-forming capabilities. Many investigators proved that the colloid materials i.e. pectins were the main constituents affecting the rheological behavior of tomato juices. With this in view it could be expected that the higher the pectin the higher the rheological values (MacDougall *et al.*, 1996 and Sharma *et al.*, 1996). Figure (4) showed that, the rheological properties (apparent viscosity at 10 rpm, consistency coefficient, and yield stress) of tomato concentrate samples had a positive correlation with total and pectin fractions contents. Exponential regression produced a better fit with total (TP), oxalate (OSP) and water soluble (WSP) pectins as shown from Figure (4) and the following equations:

TP (g $100g^{-1}$) = $4.255\ \ln(k - 282.49)$
TP (g $100g^{-1}$) = $4.357\ \ln(\tau_o - 3.1516)$
TP (g $100g^{-1}$) = $4.854\ \ln(\eta - 1193.41)$
OSP (g $100g^{-1}$) = $2.02\ \ln(k - 515.86)$
OSP (g $100g^{-1}$) = $2.082\ \ln(\tau_o - 5.7719)$
OSP (g $100g^{-1}$) = $2.188\ \ln(\eta - 1790.6$
WSP (g $100g^{-1}$) = $3.291\ \ln(k - 1306.7)$
WSP (g $100g^{-1}$) = $3.373\ \ln(\tau_o - 14.088)$
WSP (g $100g^{-1}$) = $3.763\ \ln(\eta - 3982.8)$

There was a little fit (linear regression) between rheological properties and acid soluble pectin content as shown from Figure (4).

In fact, as shown from the aforementioned equations, the best correlation was clear between the apparent viscosity and total pectin content. Youssef (2009) found positive linear regressions between rheological properties (apparent viscosity and consistency coefficient) and oxalate, acid and total pectin contents, where the correlation coefficient (R^2) values exceeded 0.85.

Effect of temperature on the viscosity of some commercial Egyptian and Yemeni tomato concentrate samples:

The change in apparent viscosity of tomato concentrate samples with temperature (5– 80°C) can be described by an Arrhenius-type equation. The parameters of this equation; activation energy (E_a) and viscosity constant (η_∞), are shown in Table (6).

The activation energy of the flow was related to some fundamental thermodynamic properties of the Newtonian fluids. For example ΔE_a was found to be approximately equal to 1/3 or 1/4 of the heat of vaporization, depending on the shape and binding of liquid molecules (VanWazer *et al.*, 1963). The activation energy (E_a) ranged from 4539.58 (Bajil brand, Yemen) to 9601.47 KJ/ Kmol (El-Rashidi brand, Egypt). Viscosity constant (η_∞) ranged from 270.45 (Al-Jawhara brand, Yemen) to 5427.32 mPa s (Bajil brand, Yemen). Ibarz *et al.* (1996 a,b) reported that the E_a decreases with increasing the pulp content. On the other hand, Manohar *et al.* (1990) reported that the η_∞ increases with the increase in total solids and pectin content. As shown in Table (6), the temperature has on the viscosity of tomato concentrate samples which was agreement with the Arrhenius equation, where the correlation coefficient values (R^2) exceeded 0.90 for all samples.

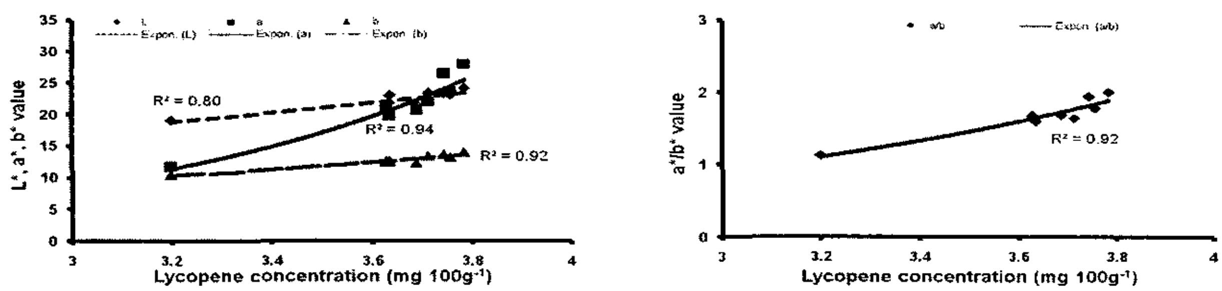

Figure (1): The exponential regressions of the lycopene concentrations with the Hunter color parameters and a^*/b^* ratio

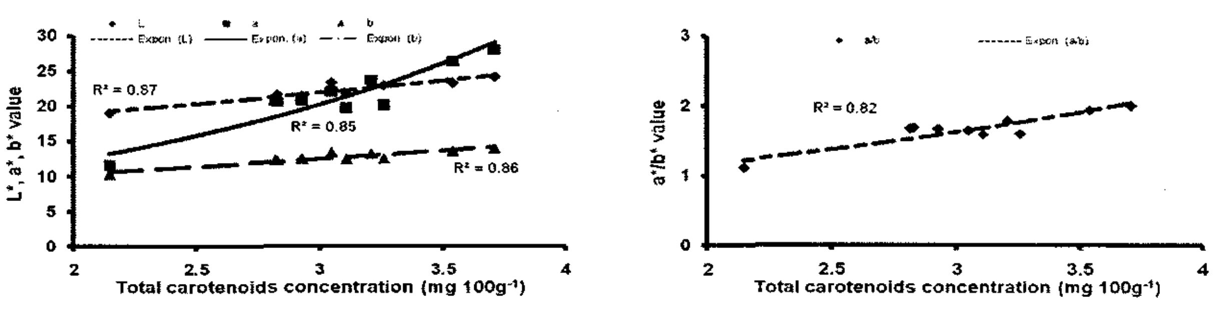

Figure (2): The exponential regressions of the total carotenoids concentrations with the Hunter color parameters and a^*/b^* ratio

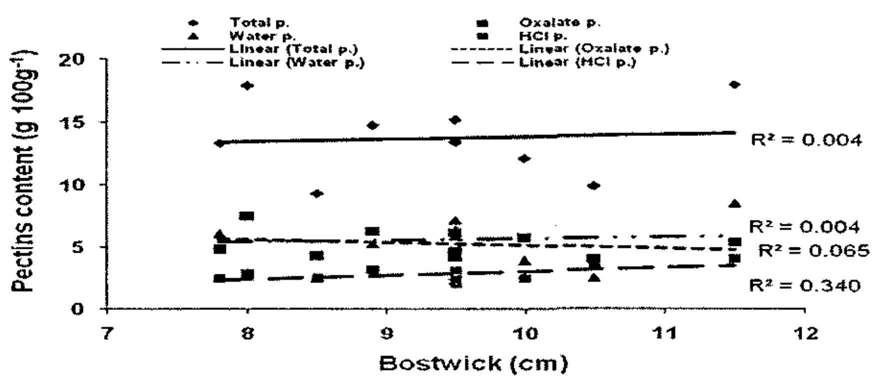

Figure (3): Linear regressions between the Bostwick consistency and pectin fractions content

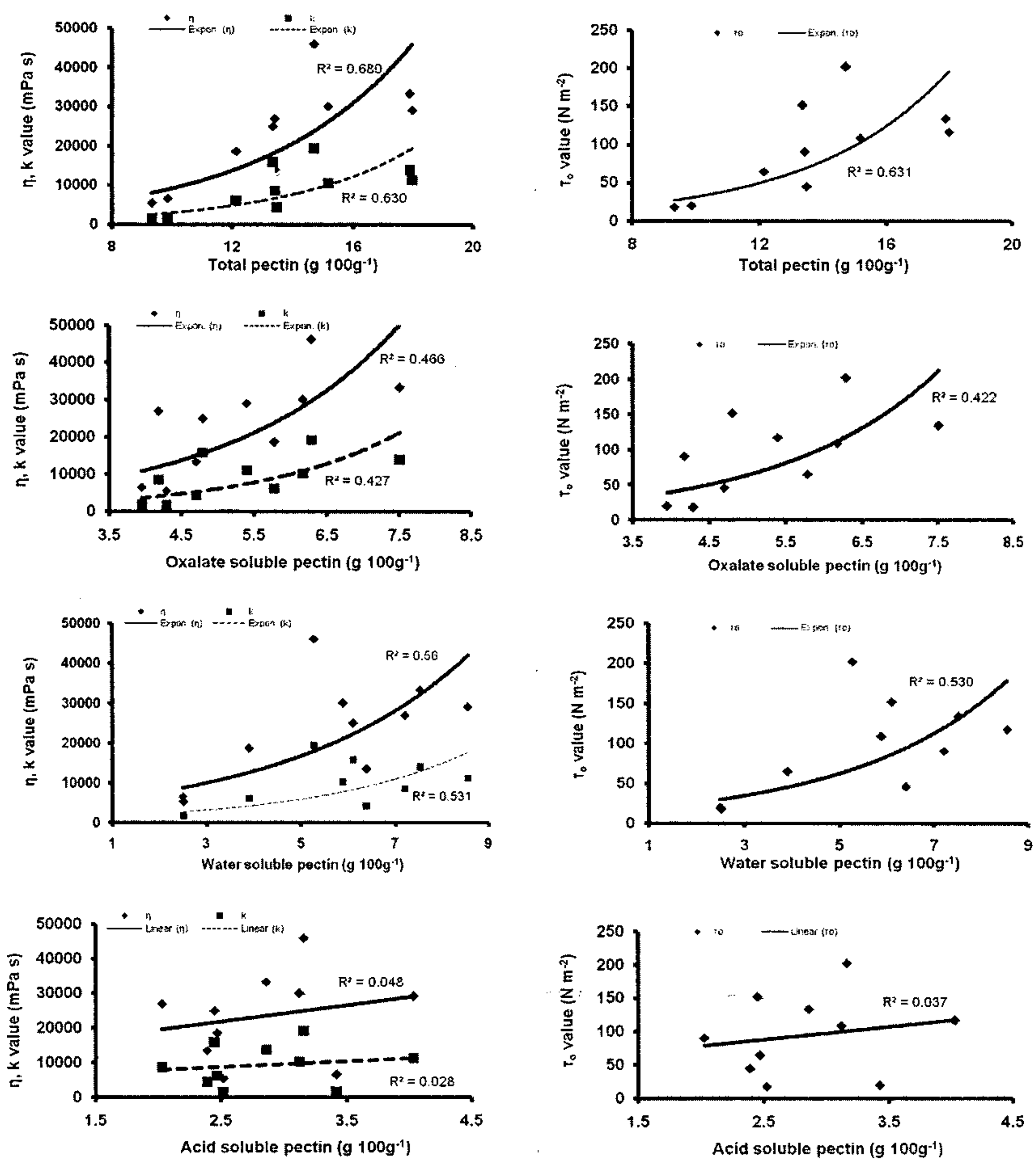

Figure (4): The relationships between the η, k, τ_o values and pectin fractions contents

Table (4): Summary of the regressions of the color reading with lycopene and total carotenoids contents of some commercial Egyptian and Yemeni tomato concentrate samples

Factor	Lycopene (mg 100g^{-1})		Total carotenoids (mg 100g^{-1})	
	Linear regression R^2	Exponential regression R^2	Linear regression R^2	Exponential regression R^2
L^*	0.78	0.80	0.87	0.87
a^*	0.86	0.94	0.87	0.85
b^*	0.89	0.92	0.86	0.86
a^*/b^* ratio	0.87	0.92	0.83	0.82

Table (5): Pectin fractions content (g 100 g^{-1}), consistency (Bostwick) and rheological properties of some commercial Egyptian and Yemeni tomato concentrate (paste or puree) samples

Item	Egyptian samples					Yemeni samples				
	EL Rashidi	Fine Foods	Foodico	Heinz	Royal	Abou Torbosh	Al Ghadeer	Al Jawhara	Bajil	Seven Star
Total pectin	12.15^e	15.18^b	14.73^c	17.99^a	17.90^a	13.42^d	9.87^f	9.33^g	13.36^d	13.49^d
Water soluble pectin	3.90^h	5.89^f	5.28^g	8.56^a	7.53^b	7.21^c	2.50^i	2.52^i	6.11^e	6.40^d
Ammonium oxalate soluble pectin	5.78^c	6.17^b	6.29^b	5.40^d	7.51^a	4.18^f	3.95^g	4.29^f	4.80^e	4.70^e
Acid soluble pectin	2.47^e	3.12^c	3.16^c	4.03^a	2.86^d	2.03^f	3.42^b	2.52^e	2.45^e	2.39^e
Consistency (Bostwick, cm)	10.0^{bc}	9.5^{cd}	8.9^{de}	11.5^a	8.0^{ef}	9.5^{cd}	10.5^b	8.5^{ef}	7.8^f	9.5^{cd}
Plastic viscosity (mPa s)	124.30^g	118.90^g	1372.00^a	684.00^b	375.00^c	251.20^d	160.80^e	63.50^h	143.00^f	126.60^g
Yield stress (Nm^{-2})	64.80^f	108.40^d	201.80^a	117.10^d	134.00^c	90.50^e	19.80^h	17.70^h	151.50^b	45.20^g
Consistency coefficient (mPa s^n)	6158^f	10311^d	19258^a	11177^d	13869^c	8593^e	1852^h	1678^h	15816^b	4295^g
Flow behavior index	0.14^c	0.11^d	0.25^a	0.09^{de}	0.08^e	0.16^{bc}	0.25^a	0.18^b	0.08^e	0.16^{bc}
Apparent viscosity (mPa s)	18691^g	30070^c	46064^a	29103^d	33308^b	26916^e	6588^i	5392^j	24947^f	13462^h

Means of triplicates
Means having the same letter within each row are not significantly different at $p= 0.05$

Table (6): Parameters of Arrhenius equation of some commercial Egyptian and Yemeni tomato concentrate (paste or puree) samples

Item	Egyptian samples					Yemeni samples				
	EL Rashidi	Fine Foods	Foodico	Heinz	Royal	Abou Torbosh	Al Ghadeer	Al Jawhara	Bajil	Seven Star
Activation energy (E_a, KJ/ Kmol)	9601.47^a	7284.50^c	5909.88^e	7161.61^c	6646.20^d	8954.61^b	7032.74^{cd}	7234.44^c	4539.58^f	7227.62^c
Viscosity constant (η_∞, mPa s)	352.59^e	1507.50^c	5425.69^a	1699.00^c	2207.46^b	700.43^d	376.72^e	270.45^e	5427.32^a	729.02^d
R^2	0.979	0.979	0.995	0.959	0.947	0.997	0.991	0.96	0.9	0.965

Means of triplicates
Means having the same letter within each row are not significantly different at $p= 0.05$

CONCLUSION

Tomato concentrate (paste or puree) brands marketed in Egypt and Yemen had a varied composition and quality attributes. The samples lied within the Egyptian and Yemeni standards in some attributes and differed in others. There were positive correlations between rheological properties especially, apparent viscosity and total pectin contents. Also, good correlations between Hunter color readings and a^*/b^* ratio of the samples and concentrations of lycopene and total carotenoids were found.

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بعض عوامل الجودة لبعض مركزات الطماطم المنتجة في مصر واليمن

عبد الله صالح السنباني- عادل أبو بكر عبد الحميد شطا- خالد محمد يوسف - صلاح كامل السماحي
قسم الصناعات الغذائية، كلية الزراعة، جامعة قناة السويس، الإسماعيلية ٤١٥٢٢، مصر

يهدف هذا البحث الي دراسة بعض عوامل الجودة لبعض مركزات الطماطم (صلصة، بيوريه) المنتجة في مصر واليمن تحت علامات تجارية مختلفة، وذلك طبقا للمواصفات القياسية المصرية واليمنية.

أوضحت النتائج المتعلقة بعوامل الجودة الكيماوية والميكروبيولوجية وجود بعض الاختلافات بين مركزات الطماطم التجارية المصرية واليمنية المختبرة عن المواصفات القياسية الموضوعة، مما يتطلب ضرورة مراقبة جودة انتاج هذه المركزات.

أوضحت النتائج أيضا وجود علاقات موجبة بين الصفات الريولوجية وخصوصا اللزوجة الظاهرية مع محتوى البكتين الكلي لهذه المركزات. كما وجدت ايضا علاقة موجبة بين قياسات اللون بواسطة جهاز هنتر ونسبة a^*/b^* وكل من تركيزات الليكوبين والكاروتينيويدات الكلية للعينات المدروسة.

كما تم دراسة تأثير درجة الحرارة علي اللزوجة باستخدام معادلة أرهينيوس. أوضحت النتائج أن للحرارة تأثيرا واضحا علي لزوجة مركزات الطماطم حيث كانت قيمة معامل الارتباط أكبر من ٠,٩٠.