Sustainable Agriculture Research; Vol. 1, No. 2; 2012
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

A Comparative Study on Physicochemical and Rheological Properties of Imported Tomato Paste in Nigeria

Sobowale, S. S.[1], Olatidoye, O. P.[2], Odunmbaku, L. A.[1] & Raji, O. H.[1]

[1] Department of Food Technology, Moshood Abiola polytechnic, Ogun State

[2] Department of Food Science and Technology, Igbinedion University Okada, Edo State

Correspondence: Sobowale, S. S., Department of Food Technology, Moshood Abiola polytechnic, Ogun State. E-mail: sunsam_2003@yahoo.co.uk

Received: November 16, 2011 Accepted: December 28, 2011 Online Published: July 5, 2012
doi:10.5539/sar.v1n2p51 URL: http://dx.doi.org/10.5539/sar.v1n2p51

Abstract

This study was carried out to evaluate the physicochemical properties and rheological behavior of a number of tomato pastes imported by Nigeria food marketers. Chemical composition, color measurement, consistency, viscometry and flow index were determined. There were significant differences among the samples and some of the parameters did not meet the standard requirements set by food drug and administration of (FDA). The viscometry consistency test and flow index at 30 ^{o}C, 45 ^{o}C and 60 ^{o}C indicated the existence of variations among the samples in terms of viscosity and flow index increase as temperature increases. All tomato paste samples in the study were non-Newtonian fluids and the apparent viscosity of the paste decreased with temperature increase. The rheological data obtained were fitted using power law equation. The differences obtained were attributed to raw materials variation and processing conditions.

Keywords: tomato pastes, physico-chemical properties, rheological behaviour

1. Introduction

Tomato (*Lycopersicum esculentum*) is a commercially important vegetable through out the world both for the fresh fruit market and the processed food industries (Atherton & Rudich*,* 1986). Apart from its characteristic flavor and aroma, it is also a good source of vitamin C and significant sources of vitamin A and B (Robinson, 1976). It has about 20-25mg ascorbic acid per 100g (Dike & Atchey, 1986). The mineral content of tomato is high and varies from 0.3 and 0.6% (Gould, 1983). Tomatoes may be consumed fresh or processed to canned whole peeled tomatoes. It may also be processed to produce juice, concentrated tomato juice, puree or paste. In tomato processing operations, tomatoes are first crushed and filtered to remove the seeds, skin and mucilage. The process results in the production of two products, tomato juice and tomato waste. The waste mainly consisting of skin and seeds is called tomato pulp or pomace. The main processing steps in the production of a tomato paste included washing, sorting, trimming, breaking, juice extraction, concentration, pasteurization, filling and cooking. After washing and sorting, the chopped tomatoes are subjected to cold break or hot break. During juice extraction the heated tomato pulp is passed through two extractors and skin. The type of extractors (Paddle or Screw) and screen size of extractors affect the quality of the final product in particular its texture and consistency (Hayes et al., 1998). According to FDA (Food and Drug Administration of the USA), "Tomato paste is strained tomatoes concentrated by evaporation with or without the addition of basil leaf, and contains not less than 24% salt free tomato solids (Luh et al., 1998). The characteristics quality factor of tomato paste depends on the quality of starting raw materials (variety and ripening stages) processing conditions (process design, time, temperature and process pressure), storage time and conditions (Farahnaky et al., 2010). Tomato paste contains both water soluble materials and insoluble components. The consistency of a tomato paste is mainly controlled by the amount of pectin, total soluble solids, and size distributions of insoluble constitute (Luh & Kean*,* 1998). The main quality parameters of tomato pastes perceive by the consumers are color, consistency and flavor, in addition there are compositional standards (Farahnaky et al., 2010). One of the problems facing the companies for exporting tomato pastes is variation in color and consistency of their products. The step in solving these problems is to characterized this specific type of foods, and classify them based on the criteria set by the international recognized organization such as FDA (Food and Drug Administration).

The focus of this study was to compare the physicochemical properties and rheological behavior of a number of tomato pastes imported to Nigeria market by Nigeria food processors and evaluates the variation in their consistency, color and composition.

2. Material and Methods

2.1 Material

Tomato pastes (eight 70g of each brand) from ten different tomato paste producing companies with nearly the same production dates were locally purchased from local markets in Ogun State, Nigeria. The tomato paste sample included: Gino, Toma, Ciao, De-rica, La cato, tasty tom, Rosa, De-mimi , Vitali, and Napa tomao paste with nearly the same production year and the customer price of each 70g in sealed can and sachet of different brands was N40, N40, N30, N50, N30, N30, N30, N30, N30 and N30, respectively.

2.2 Methodology

The sealed cans and sachet tomato paste were kept in a cold room set at 4^0C for the experiments. The sealed can and sachet tomato paste kept in the cold room were taken out for the progressive determination of characteristic quality factors of tomato paste. All chemicals used in this research were of analytical grade and all the test was performed in triplicate.

2.2.1 Physico-chemical Analysis of Tomato Pastes

Total soluble solid (Brix), reducing sugar, ascorbic acid, salt content and pH of the tomato pastes were quantitatively determined according to the Association of Official Analytical Chemists (AOAC, 1990) method.

2.2.2 Color Measurement of Tomato Pastes

The color of tomato paste samples was evaluated using a modified method of Yam et al. (2004). Each sample was carefully poured into a Petri dish to avoid formation of any air bubbles on the surface. The Petri dish was covered using a layer of clear cling film. The color parameters of L, a and b were determined in the “Lab” mode of the software.

2.2.3 Determination of Rheological Properties of Tomato Pastes

Rheological properties of tomato paste samples were studied using a controlled shear stress rheometer (Deer rheometer, Model PDR, 81, UK) at three temperatures (30, 45 and 60°C). The tests were performed in triplicate using a cone and plate geometry with the cone angle of 4o. The geometry edges were covered by applying a small amount of low viscosity oil for tests performed at high temperatures to minimize moisture loss. The obtained empirical data (torque and angular velocity) were converted into shear stress and shear rate parameters using Equations 1 and 2. The values for the flow behavior index n; and the apparent viscosity (μ) were obtained by fitting the experimental data into a “Power Law equation” (Equation 3) using the “Solver” in Excel program (Microsoft Office, 2003). Apparent viscosities of the samples were then calculated at shear rate of $15s^{-1}$ and compared.

$$\gamma = A.V/ \tan \Theta \quad (1)$$

where γ is the shear rate (s^{-1}), A.V is angular viscosity (Rad . s^{-1}) and Θ is the cone angle of the geometry.

$$\sigma = 3\ \tau / 2\Pi R3 \quad (2)$$

the σ is shear stress (dyne.cm^{-2}), τ is torque (dyne . cm) and R (cm) is the radius of cone and plate geometry.

$$\sigma = \eta\ \gamma n + \sigma 0 \quad (3)$$

where η is viscosity (centiPoise, cP), n is flow behavior index and σ_0 is yield stress.

2.3 Statistical Analysis

All data were analyzed by randomized plot using SPSS and were subjected to analysis of variance, followed by a Duncan’s multiple-range test analysis. Significance level was set at $\alpha = 0.05$. All tests were performed at least in triplicate (Steel & Torrie, 1980).

3. Result and Discussion

3.1 Physico-chemical Properties of Tomato Pastes

According to the FDA, 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 29 to 33% of salt free tomato solids and light pastes, 25 to 29% (Luh & Kean, 1998). The result of physico-chemical analysis tests (Table 1) indicate that the total Brix of tomato pastes varied from 25.5 to 31.3%. However in the

FDA, the "salt free Brix" is regarded as the standard criterion for tomato paste. The salt free Brix of the tomato pastes ranged from 22.73 to 30.68% and most of the samples were in the range of 25-26%. The pH values of the pastes was in the range of 4.87-5.30.Ciao has the highest pH values and De-mimi has the least values and there was significant different between the samples under study. The standard pH of tomato paste range between 3.8-4.3 (Hayes et al., 1998). Since tomato pastes are pasteurized and not sterilized, low pH is an important factor for microbial stability in preventing the growth of pathogenic microorganisms and a proper and routine checking of pH of the final products by the manufacturers is required. The total solid is used to measure moisture content. The total solid content of the samples varied from 54.9-68.90. De-Rica has the highest total solid content and tasty tom has the least values. According to food standard, total solid should be of high content. The higher the total solid the good the quality of the tomato paste. Tomato fruit is a good source of vitamin C (about 140mg/100g) and it is of great important to investigate the level of residual vitamin C in tomato pastes. Heat and oxygen are among the main factors causing loss of vitamin C in tomato processing (Gloria et al., 2005). Nutritionally a food manufactured would try to minimize the loss of vitamins during processing and storage. Therefore the concentration of vitamin C in a tomato pastes can be counted upon as an indicative of processing conditions as well as raw material quality. The level of vitamin C in tomato pastes was very different and ranged from 12.60 to 17.20mg/100g. De-Rica has the highest vitamin C and Vitali has the least values. A severe and long heat processing during the evaporation of water from the tomato juice can be one of the main reasons for this difference. The comparison of the levels of vitamin C found for the tomato paste samples of this study show that a large quality of the vitamin C in tomato fruit is degraded during the processing and storage. The addition of sugar to tomato paste, as distributed in commercial processing is not generally permitted but it may occasionally be required to determine if additional sugar is contained in the course of some manufacturing process, or if a sample has been adulterated. The reducing sugar content of the samples varied from 1.3% (w/w) (with lowest brix of 42.60) to 2.6% (with highest brix of 76.60) which is determined by the reducing sugar content of the tomato fruits used and the brix of the tomato paste. Nearly half of the dry matter of tomato is reducing sugars (glucose and fructose) (Luh & Kean, 1998). Salts are added to tomato paste to give flavor and for preservation because of the concerns over health related issues regarding high intake of salt by the consumers, the level of salt in different foods has recently become the focus of many research projects (Farahnaky and Hill, 2007). As an important issue the salt content of the samples was measured. The salt content of the sample was very differently and ranged from 0.6-2.5% (w/w), tasty tom had the highest salt and De-mini had the least values. According to the Food and Drug Administration (FDA) the maximum salt content of tomato paste is 2% (w/w). The salt levels reveal that the total intake of salt by the consumption of tomato pastes can be considerable if a large quantity is consumed and only two of the tomato paste in this study can be considered as a high salt product.

Table 1. Physicochemical properties of tomatoes paste (g/100g, wet basis)

Sample	pH	Total Solid (%)	Ascorbic Acid (mg/100g)	Reducing Sugar (%)	Salt Content	TSS (Brix %)
De-Mimi	4.87± 0.04f	57.40±0.3f	13.70± 0.01b	1.90 ± 0.02h	0.68 ± 0.02ef	48.40±0.3g
Vitali	4.95±0.03e	61.70±0.4e	12.60 ±0.02c	2.10 ± 0.0cd	1.10 ± 0.01ef	60.40±0.2d
Rosa	5.01±0.03a	58.80±0.2a	13.40± 0.00d	1.40 ± 0.01g	2.40 ± 0.02a	42.60±0.4a
Tasty-Tom	4.88±0.02d	54.90±0.3cd	12.70±0.01bc	1.30 ± 0.0d	2.50 ± 0.05de	44.10±0.3e
Ciao	5.30±0.03c	67.70 ±0.1b	16.70±0.00bc	2.40 ± 0.02e	1.60 ± 0.03cd	76.40±0.1c
Toma	4.97±0.05e	56.90 ± 0.4e	14.80 ± 0.01c	2.60 ± 0.00c	1.70 ± 0.04b	69.40±0.0b
Napa	5.10±0.01dc	60.70±0.0cd	13.50± 0.01b	1.66 ± 0.01b	1.30 ± 0.01f	58.60±0.2f
Gino	5.05± 0.03b	59.60 ± 0.4e	12.80 ± 0.00a	1.60± 0.01fe	1.84 ± 0.02g	66.70±0.3e
De-Rica	5.20 ± 0.03c	68.90±0.2bc	17.20±0.01cb	1.84 ± 0.0f	1.32 ± 0.00cd	68.70±0.0c
La- Cato	4.96 ± 0.04c	67.40±0.1de	14.10 ± 0.00a	1.75 ± 0.01a	1.44 ± 0.05c	70.10±0.1d

*Data are an average (1SD) of triplicate trials. Different letters in each column indicate that the values differ significantly at α=0.05.

3.2 Color of Tomato Paste

Lightness and a/b ratio reported as the indicative and quality parameters for the color of tomato products (Hayes et al., 1998) of the samples were measured to quantify the extent of the color difference between tomato pastes samples. The L value of the sample (Table 2) were significantly different and ranges from 48.5 (the darkest) to 59.0 (the lightest). A one unit difference in L value of two samples can be detected by the human eyes. There was also a significant difference between the tomato pastes in terms of a/b ratio which varied from 1.4 to 2.10 (Table 2). According to (Goose and Binsted, 1964) an a/b ratio of 1.9 or greater represents a top quality product in terms of color and an a/b ratio of less than 1.80 indicates that the paste may be unacceptable the results Table 2 show the minimum requirement for a quality product were not met for some sample.

Table 2. L. a, b, and a/b color parameters of tomato paste samples

Sample	L	A	B	a/b
De-mimi	52.4 ± 0.1h	6.7 ± 0.1i	4.8 ± 0.0h	1.40 ± 0.0b
Vitali	55.0 ± 0.0g	16.6 ± 0.2i	9.8 ± 0.1i	1.80 ± 0.0ab
Rosa	60.0 ± 0.2c	24.6 ± 0.1d	11.9 ± 0.2d	2.07 ± 0.0ab
Tasty-Tom	61.0 ± 0.0e	25.6 ± 0.0g	12.2 ± 0.3e	2.10 ± 0.0ab
Ciao	59.0 ± 0.2f	19.1 ± 0.2f	9.7 ± 0.2f	2.00 ± 0.0a
Toma	53.2 ± 0.0a	11.0 ± 0.0a	6.9 ± 0.1a	1.60 ± 0.0ab
Napa	50.1 ± 0.2b	6.9 ± 0.1b	4.9 ± 0.1b	1.4 ± 0.0ab
Gino	54.4 ± 0.0c	16.8 ± 0.1c	8.6 ± 0.1c	2.0 ± 0.0a
De- Rica	49.2 ± 0.2d	7.3 ± 0.2e	5.2 ± 0.1e	1.4 ± 0.0a
La-Cato	53.8 ± 0.1e	11.1 ± 0.1h	6.2 ± 0.0g	1.8 ± 0.0ab

*Data are an average (±1SD) of triplicate trials. Different letters in each column indicate that the values differ significantly at =0.05. L = Lightness a = Red saturation index value, b = Yellow saturation index value.

3.3 Rheological Behavior of Tomato Pastes

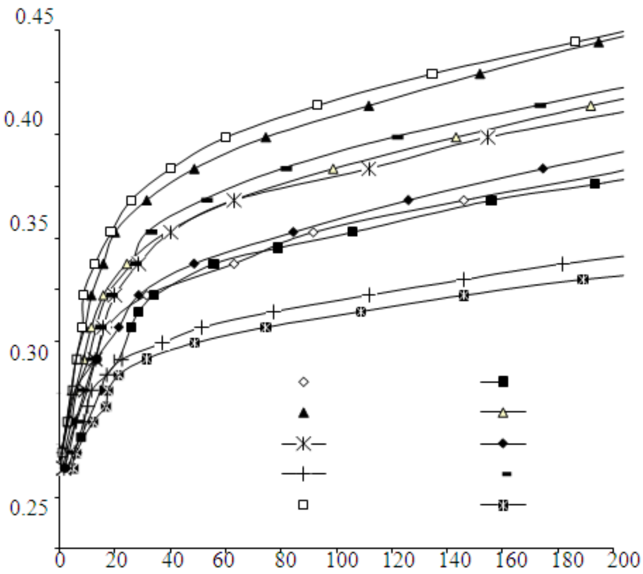

Figure 1. Shear stress-shear rate curves

Shear stress-shear rate curves (Figure 1) obtained from the rheological tests indicated that all tomato pastes in this study were non-Newtonian fluids and the flow behavior index values obtained (Table 3) indicate that the examined fluids were all pseudoplastic (shear thinning). The apparent viscosities of the samples decreased with increasing shear rate (Figure 1), therefore all tomato pastes were susceptible to shear thinning, a characteristic of pseudoplastic foods. Similar results have been reported by Dale et al., 1984; Steffe, 1996), who showed that the viscosity of tomato products depends on fiber, protein, fat contents and total soluble solids. They also developed an empirical equation for apparent viscosity of the products depending on the chemical composition.

The consistency of the tomato pastes samples varied from 7.40 to 12.10 (Table 3) which determined the smoothness and thickness of the tomato paste sample and there was significant different between the sample. The results presented in Table 4 also show that increase in temperature resulted in a significant reduction in the apparent viscosity. Consistency of viscous materials measured the thickness and smoothness of the materials. When a tomato paste sample is subjected to a low shear stress the matter does not flow and only after reaching a certain level of stress (called yield stress) it starts to flow. The yield stress of tomato – based products is of great importance as to consumer (for pouring behavior) and processing design (materials handling) parameter. As expected, the yield stress of the sample can be affected by temperature, the higher the temperature the lower the yield stress. At 30oC the highest flow index is 3.80 and the least is 2.10 and there was significant different between the sample. The highest flow index at 300C increases to 3.96 at 450C because of the increase in temperature and increase to 4.80 at 600C due to increase in temperature.

Table 3. Rheological properties of Tomato Paste (g/100g), wet basis

Sample	Viscosity	Consistency	Flow behavior index (^{0}C)		
			30 ^{0}C	45 ^{0}C	60 ^{0}C
De-Mimi	3.40 ± 0.2b	12.10 ± 0.2c	3.80 ± 0.1e	3.96 ± 0.1j	4.80 ± 0.1g
Vitali	4.10 ± 0.3e	10.60 ± 0.2h	2.90 ± 0.2a	3.20 ± 0.1b	5.10 ± 0.1b
Rosa	5.20 ± 0.4a	8.74 ± 0.4f	3.10 ± 0.1c	3.70 ± 0.2g	4.96 ± 0.3i
Tasty -Tom	4.00 ± 0.1bc	9.68 ± 0.2b	2.84 ± 0.1d	2.94 ± 0.1i	3.86 ± 0.1e
Ciao	3.70 ± 0.3b	11.40 ± 0.2e	3.10 ± 0.0c	3.57 ± 0.0e	5.20 ± 0.2h
Toma	3.20 ± 0.2b	10.74 ± 0.1d	2.90 ± 0.3c	2.97 ± 0.0d	3.40 ± 0.1c
Napa	5.60 ± 0.3f	8.75 ± 0.1c	2.60 ± 0.1c	2.78 ± 0.1c	3.69 ± 0.2j
Gino	4.70 ± 0.4cd	9.20 ± 0.3i	3.00 ± 0.0b	3.60 ± 0.2f	3.74 ± 0.1d
De-Rica	3.60 ± 0.0d	7.40 ± 0.1g	2.50 ± 0.0c	2.74 ± 0.0h	2.80 ± 0.2f
La- Cato	3.70 ± 0.1e	8.60 ± 0.0j	2.10 ± 0.2b	3.07 ± 0.1a	3.34 ± 0.1a

*Data are an average (±1SD) of triplicate trials. Different letters in each column indicate that the values differ significantly at α=0.05.

Table 4. The apparent viscosity*(cP) of tomato paste samples at different temperatures and shear rate 15/s

Temperature(ºC) Sample	30 ^{0}C	45 ^{0}C	60 ^{0}C
De-mimi	32.0±0.1gG	18.0±0.1fF	12.0±0.1fF
Vitali	33.0±0.2gG	21.0±0.1efEf	26.0±0.1bB
Rosa	45.0±0.1fF	25.5±0.2cdCd	17.0±0.3eE
Tasty-tom	48.0±0.1ee	21.0±0.1efEf	19.0±0.1eE
Ciao	54.0±0.0dd	24.0±0.0deDe	19.0±0.0eE
Toma	62.0±0.3cc	26.0±0.0bcdBcd	23.0±0.2cdCd
Napa	63.0±0.1cc	28.5±0.2bcBc	25.5±0.1bcBc
Gino	64.0±0.1cc	34.5±0.1aA	30.0±0.1aA
De-rica	72.0±0.0bb	29.0±0.2bB	22.5±0.2dD
La-cato	90.0±0.1aa	36.0±0.1aA	26.5±0.1bB

4. Conclusion

The tomato paste studies in this research were representative of most tomato paste imported to Nigeria. In terms of composition there were significant differences among the sample particularly in total solid and ascorbic acid (vitamin C) content. According to the FDA (Food Drug and Administration) definitions for tomato paste, this work showed that some of the tomato pastes studied in this research prove to meet the minimum requirement standard. If vitamin C is taken as an indicator of the level of all vitamins remained in the pastes, after heat processing and storage, it can be concluded that the level of vitamins is low compared to starting raw materials (fresh tomatoes). In terms of color and rheological properties there were significant differences among the samples. The variations in the raw materials and the lack of standard operating procedure with consistency process conditions would be the main reasons for such a wide variation in the quality of tomato pastes imported to Nigeria market.

References

Atherton, J. G., & Rudich, J. (1986). *The Tomato Crop Chapman and Hall.* London, UK

Dike, A. J., & Atchley, A. A. (1986). *Handbook of Proximate Analysis Tables for Higher Plants.* CRC Press Inc. Florida.

AOAC. (1990). Official Methods of Analysis. (15th ed.). Association of Official Analytical Chemists, Inc. Washington D.C, USA.

Dale, K. B., Okos, M. R., & Nelson, P. E. (1984). Concentration of tomato products: analysis of energy saving process alternatives. *J. of Food Sci, 47*, 1853-1858. http://dx.doi.org/10.1111/j.1365-2621.1982.tb12898.x

Farahnaky, A., & Hill, S. E. (2007). The effect of salt, water and temperature on wheat dough rheology. *J. of Texture Studies, 38*, 499-510. http://dx.doi.org/10.1111/j.1745-4603.2007.00107.x

Gloria, S. Z., Yahia, E. M., Jeffrey, K., & Gardea, A. (2005). Effects of post harvest hot air treatments on the quality and antioxidant levels in tomato fruit. *LWT, 38*, 657-663. http://dx.doi.org/10.1016/j.lwt.2004.08.005

Goose, P. G., & Binsted, R. (1964). T*omato Paste Definition, Characteristic and Quality. Chap.1 In Tomato Paste, Puree, Juice And Powder*. Food Trade Press LTD, London.

Gould, A. W. (1983). *Tomato Processing, Tomato Production, Processing and Quality Evaluation.* Avi Publico. Inc. Westport, Connecticut. p. 112.

Hayes, W. A., Smith, P. G., & Morris, A. E. J. (1998). The production and quality of tomato concentrates. *Crit. Rev in Food Sci. and Nutr, 38*, 537-564. http://dx.doi.org/10.1080/10408699891274309

Luh, B. H., & Kean, C. E. (1998). Canning of Vegetables In: Commercial Vegetable Processing. Luh, B.H and J. G. Woodroof (ed).Van Nostrand Reinhold, New York. pp. 195-285.

Robinson, R. W. (1976). *Tomato. Encyclopedia of Food Agriculture and Nutrition.* (4th ed.). MC Graw Hill Inc. New York, 650-652.

Steel, R. G. D., & Torrie, J. H. (1980). Principles And Procedure Of Statistics. (2nd ed.). MC Graw-Hill Book Co; New York.

Steffe, J. F. (1996). *Rheological Methods in Food Process Engineering*. (2nd ed.).

Yam, K. L., & Papadakis, S. E. (2004). A simple digital imaging method for measuring and analyzing color of food surfaces. *J. of Food Eng, 61*, 137-142.