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Evaluation of the microbiological and physico-chemical characteristics of local tomato '*Solanum lycopersicum*' puree produced on a small scale in Togo

Mawuena Gott'liebe Goka[1,2*], Marie Dufrechou[2], Pierre Picouet[2] and Yaovi Ameyapoh[1]

[1]LAMICODA, Ecole Supérieure des Techniques Biologiques et Alimentaires (ESTBA), 1515, Lomé, Togo.
[2]USC 1422 GRAPPE, INRA, Ecole Supérieure d'Agricultures, SFR 4207 QUASAV, 55 rue Rabelais, BP 30748, 49007 Angers Cedex 01, France.

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Tomatoes are produced, processed and widely consumed by the Togolese population. However, the local production is not developed enough to be able to provide locally processed tomatoes. In order to promote local development, stimulate local processing and reduce post-harvest losses, the processing into puree was undertaken with three locally grown varieties of tomatoes in Togo (Aklikonvi, Tohounvi, and Pomvi). A method developed at the LAMICODA laboratory was used and the process was adapted to be mastered by any local producers. Microbiological and physico-chemical analysis of crushed tomatoes and tomato purees of the three different varieties were performed in order to validate product stability and to determine final product physico-chemical and nutritional qualities. Results showed that the hygienic quality of these tested products was validated according to the criteria considered by the European Union. Also, the results indicated that purees produced contained lycopene (3.94 mg to 7.36 mg/100 g), vitamin E (0.38 mg to 1.14 mg/100 g), β-carotene (0.27 mg to 0.56 mg/100 g), and sugars (such as fructose: 0.75 g to 1.56 g/100 g; glucose: 0.78 g to 1.52 g/100 g) whatever the variety. The total sugar content is significantly different ($p<0.05$) for crushed tomatoes and purees. A deterioration of the color and an increase of the acidity were observed in the obtained tomato purees. These preliminary results obtained on these processed products are helpful for further processing and promotion of these different varieties of locally grown tomatoes in Togo.

Key words: Local tomato, crushed tomato, tomato puree, hygienic quality, physicochemical quality, Togo.

INTRODUCTION

Tomatoes are widely consumed around the world and in 2017 its production is estimated at 182 million tons worldwide, of which 21 million tons in Africa and 13 328.2 tons in Togo (FAO, 2018). In Togo, tomato production remains seasonal, artisanal and unorganized (Dossou et al., 2007). Nethertheless, Togolese tomato production remains the priority activity of 65% of the population in the Savanna region in the north of the country and one

*Corresponding author. E-mail: Liebe176@yahoo.fr.

of the most important income-generating activities for local producers in Togo (Anonyme 1). Three main varieties are cultivated: Aklikonvi, Tohounvi, and Pomvi. The production period includes a period of shortage from October to May and a period of abundance from June to September. Due to this production period, fresh tomatoes and processed tomatoes are imported from bordering countries such as Ghana and Burkina-Faso (Malet, 2017) but not only. Some Togolese companies are specialized in tomato processing into puree; however despite their production, a postharvest loss of tomatoes is observed in Togo (Anonyme 2), due to a lack of processing method that could be done directly by local producers. Also, the tomatoes are of interest due to its rich content in mineral elements such as potassium, vitamins (A, C, E) (Sadok and Zedak, 2016; Dossou et al., 2007) and different antioxidants compounds such as phenolic compounds (mainly rutin, naringenin, and chlorogenic acid), carotenoids (mainly lycopene and β-carotene) (Toor and Savage, 2005; Chanforan, 2010). These antioxidants make it a formidable bulwark against diseases (Sadok and Zedak, 2016). This composition of fresh tomatoes can vary significantly, especially depending on the varieties but also growing conditions (agricultural techniques and environmental factors) or post-harvest preservation that can lead to compositional variability within the same cultivar (Hernandez et al., 2008). It is obvious that heat treatments have an effect on the biochemical and nutritional composition of food. This effect can be positive on certain compounds such as lycopene improving their absorption by the body (Boumendjel et al., 2012). However to our knowledge, no studies were assessed on Aklikonvi, Tohounvi, and Pomvi varieties composition and its processed product.

Also, our previously carried out investigations have revealed that currently these varieties tend to disappear and to be replaced by hybrid varieties, more resistant to damage and extreme weather conditions. This study therefore aims (1) to propose a method to preserve tomatoes using a process adapted to be mastered by any local producers. Some microbiological analysis will be performed to validate the quality of the process applied to obtained tomato puree. (2) To obtain information about physico-chemical characteristics and nutritional composition of the main compounds (sugar content, fibers, antioxidant, vitamins) of Aklikonvi, Tohounvi, and Pomvi tomatoes varieties before and after processing into puree.

MATERIALS AND METHODS

Varieties of tomatoes

The three main varieties of tomatoes grown in Togo were studied: The variety "Pomvi" is a smooth round fruit grown in the north in the Savannah region of northern Togo, the varieties "Aklikonvi" elongated fruit and "Tohounvi" slightly rounded fruit flattened and lobed grown in the south in the Maritime region in the prefectures of the Lakes, Bas-Mono and Vo. Twenty-five kilograms of each tomatoes were bought at the Lomé Grand Market in August and October, 2018. These raw tomatoes were then stored for a week at room temperature (28-32°C), out of the indirect sunlight, to reach optimum maturity before processing.

Process applied for tomato puree production

Tomato purees were obtained using a process easily transferable to local producers, at the laboratory LAMICODA in Lomé (TOGO). The raw tomatoes (25 kg) were sorted to remove rotten tomatoes and then washed three times with clean water. Raw tomatoes were crushed using a manual tomato crusher (TRE SPADE, Ptoclamm and Ptoclaii, Grecostore, Italy) to separate the skin and seeds from the pulp. At this stage, 21±1 kg of crushed tomatoes was obtained. For each variety, samples of 200 g of crushed tomatoes (CT) were directly packed into a double-closure freezer bag (Ultra-Zip, Alba Melitta Group) and stored at -20°C before analysis. They will be used as control sample. Crushed tomatoes were cooked during 30 min at 90°C in a saucepan under manual stirring, then concentrate using a clean linen for filtration. Tomato puree obtained were packaged in 25 cL sterilized glass bottles and were pasteurized at 75°C during 30 min in order to guarantee the hygienic quality of the finished product. The pasteurized tomato purees (TP) were stored at room temperature. For each variety (Aklikonvi, Tohounvi, and Pomvi) and each period of harvest (August and October), samples of crushed tomatoes (CT) and samples of pasteurized tomato purees (TP) were obtained. Microbiological analysis was done the next day after total cooling of the pasteurized purees. All samples were analyzed at least in triplicate at LAMICODA, Lomé, Togo for microbiological analysis and the USC GRAPPE in Angers-France for physico-chemical analyses.

Evaluation of the microbiological quality of tomato purees

Microbiological analysis was carried out on tomato purees in order to evaluate their hygienic quality and validate their preservation at room temperature. Each variety, for each period of harvest was analyzed following microbiological requirement recommended by European Union (Regulation 178/2002/EC; updated the 24/05/2007). It includes total mesophilic aerobic flora (PCA, 30°C, 24-48 h), total and thermotolerant coliforms (VRBL agar, 30°C or 44°C, 24-48 h), sulfite-reducing anaerobic bacteria (TSN agar, 37°C, 24-48 h), yeasts and molds (Sabouraud + Chloramphenicol agar, 30°C, 48-72 h). Each analysis was done in triplicate.

Evaluation of the conventional physico-chemical parameters

pH, titratable acidity and soluble solids content

pH and titratable acidity were determined using respectively a pH meter (Orion Star A111-Thermo Scientific) and an automatic titrator (877 Titrino Plus, Metrohm). For titratable acidity, diluted mixture of 10 g of sample and 25 ml of deionized water was titrated with sodium hydroxide (0.1N NaOH) to reach pH 8.1 (NFV05-101). The results are expressed as citric acid equivalent per 100 g (conversion factor of 0.07). Soluble Solids Content (°Brix) was measured using a refractometer (Refracto 30PX- Mettler Toledo). Each analysis was done in triplicate.

Color measurement

Color analyses were performed using the spectrocolorimeter (CM-

700, Konica-Minolta) with a D 65 illuminant and CIE (10°) observer as technical characteristics. Color change was described as L*, a* b* and five repetitions were made for each sample. The redness of crushed tomatoes and tomato puree was determined by a*/b* ratio. The color difference (ΔE*) between two samples was determined using Equation 1.

$$\Delta E^* = \sqrt{((L^*_e - L^*_{ref})^2 + (a^*_e - a^*_{ref})^2 + (b^*_e - b^*_{ref})^2)} \quad (1)$$

Where L^*_{ref}, a^*_{ref}, b^*_{ref} are the reference values and in this case, it is the values of the crushed tomatoes taken as reference and L^*_e, a^*_e, b^*_e being the values of the tomato purees.

Evaluation of nutritional compounds

Sample preparation before analysis

Crushed tomatoes samples and tomato purees samples were frozen at -80°C during 12 h before using the freeze dryer (VirTis *SP* SCIENTIFIC *Sentry* 2.0). 200 g of samples were freeze dried during 7 days in order to remove water content and to obtain a dry powder.

Chemicals solution for analysis

The standards used in this study were: D-(+)-Glucose, D-(-)-Fructose and Sucrose (≥ 99%, Sigma Aldrich), Lycopene (analytical standard, Sigma Aldrich), Beta-carotene (>97%, Sigma Aldrich) and α-Tocopherol (analytical standard, Sigma Aldrich), Naringenin (>98%, Sigma Aldrich), Chlorogenic acid (≥ 98%, Fluka), Coumaric acid (>98%, Acros Organics), and Rutin (>99%, ExtraSynthese). The HPLC grade solvents used were purchased from Fischer Scientific: Acetone, Acetonitrile, Methanol, Hexane, Tetrahydrofuran, and Trifluoroacetic acid.

Sugar content (Glucose, fructose)

The main sugars (fructose and glucose) were quantified by Agilent Model 1200 HPLC (Agilent Technologies, USA) coupled to an Evaporative Light Scattering Detector (ELSD) (Sedere, France). The extraction method was developed by the USC GRAPPE. 50 mg of crushed tomatoes or tomato puree were mixed with 1.5 ml of distilled water and vortexed for 1 min. Samples were then placed on stirring plate for 20 min and were centrifuged at 15000 rpm, 20°C, and 15 min. The supernatant was collected and filtered using nylon filter (0.45 µm/13 mm, Interchim) before injection of 20 µl on HPLC/ELSD. The column Rezex RCM-Monosaccharide Ca^{2+} (300×7.8 mm, Phenomenex) was used at 70°C with 100% demineralized water at a flow rate of 0.5 ml/min. ELSD parameters were a nebulization temperature of 40°C and 2 bars of pressure. Analysis was done in triplicate.

Fiber content

Fiber content or alcohol insoluble matter (AIM) was determined by the gravimetric method according to gravimetric method according to Renard (2005a). 1 g of freeze-dried tomato puree was suspended in 20 mL of 70% ethanol. The mixture was stirred for 10 min, transferred to a 75 mL separating column (Sep-pak, Interchim) equipped with a 20 µm filter and filtered under vacuum. The pellet obtained was recovered and the operation was repeated 12 to 15 times. The first two washing were performed with 70° ethanol heated to 80°C in order to inactivate the endogenous enzymes of the fruit. The following 13 washing were carried out with unheated 70° ethanol. The absence of soluble sugars in the filtrate was measured by the sulfuric phenol method described by Dubois et al. (1956). The pellet was dried after 3 washing with 30 mL of 96% ethanol followed by 3 washes with 10 mL of acetone, then placed overnight in an oven at 40°C. The net mass of alcohol-insoluble material gives an estimate of the total fiber content of the sample (expressed as a percentage of the total content of the sample expressed as % of fresh tomato).

Polyphenol content

The analysis of rutin, chlorogenic acid, naringenin content and the evaluation of total polyphenol content was carried out by an Agilent Model 1200 HPLC (Agilent Technologies, USA) according to the method developed at USC GRAPPE laboratory. 3 solvents were used for extraction: solvent 1 (100% methanol), solvent 2 (30% distilled water, 70% acetone, 0.05% trifluoroacetic acid), solvent 3 (89% distilled water / 10% methanol / 0.1% hydrochloric acid 37%). 500 mg of the lyophilizate sample was mixed with 20 ml solvent 1 and then vortexed during 1 min.

After 10 min, the supernatant was collected and placed in a centrifugal evaporator (miVac, Genevac) at 30°C during 1 to 2 h. This step was done twice, adding 20 ml of solvent 2. Then 1.5 ml of solvent 3 was added. The mixture was placed on a stirring plate during 10 min then centrifuged at 10000 rpm, 15°C, 10 min. Supernatant was filtered (PTFE filter of 0.45 µm/13 mm) before injection of 5 µL. Column Kinetex C18 (150×4.6 mm, Phenomenex) was used at 30°C at a flow rate of 1 ml/min. A gradient elution using solvent A (95% distilled water / 5% formic acid) and solvent B (80% Acetonitrile / 15% distilled water / 5% formic acid) was applied as followed: 3 min 97% solvent A / 3% solvent B, 3 to 34 min to reach 20% solvent A / 80% solvent B. Measurements were done at 280 nm for total polyphenol content and naringenin, 320 nm for chlorogenic acid and 360 nm for rutin. Analysis was done in triplicate.

Carotenoid content (beta-carotene, lycopene) and α-tocopherol

Analysis of carotenoid (beta-carotene and lycopene) and α-tocopherol (or vitamin E) was carried out using an Agilent Model 1200 HPLC (Agilent Technologies, USA). 1 mL of hexane was added to 50 mg of freeze-dried sample. The mixture was vortexed 30 s, placed on the stirring table (10 min, maximum speed) then centrifuged at 4°C, 10 min, and 15000 rpm. The supernatant was placed in a centrifugal evaporator (miVac, Genevac) at 30°C during 30 min to obtain the total evaporation of the hexane. Once evaporated, 1 ml of the solvent (20% Acetonitrile + 80%Tetrahydrofuran) was added. The mixture was vortexed 30 s and filtered using PTFE filter (0.45 µm) before injection of 5 µL. Column Kinetex C8 (150×4.5 mm with pre-column C8, Phenomenex) was used at 60°C at a flow rate of 1 ml/min. A gradient of elution was used with 2 mobile phase: A (70% Methanol / 30% Ammonium Acetate 1 M) and B (60% distilled water, 40% Methanol). Gradient analysis was applied as followed: 0 min 60% solvent A / 40% solvent B, 0 to 40 min to reach 15% solvent A / 85% solvent B. Measurements were done at 295 nm for α-tocopherol, 450 nm for lycopene and 470 nm for beta-carotene. Analysis was done in triplicate.

Statistical analysis

A statistical analysis was performed on the different samples using the Statgraphics Centurion 18 software at a $p < 0.05$ threshold with

Table 1. Microbiological analysis of tomato puree.

Germs	Number of germs in pasteurized tomato purees			European Union (EU) criteria, Regulation 178/2002/EC; updated on 24 May 2007
	Aklikonvi	Tohounvi	Pomvi	
Mesophilic aerobic flora	<10	<10	<10	10^4/1 g of puree
Total and thermotolerant Coliforms	Absent	Absent	Absent	Absent /1 g of puree
Sulfite-reducing anaerobic bacteria	Absent	Absent	Absent	Absent /1 g of puree
Yeasts and Molds	Absent	Absent	Absent	10^4 /1 g of puree

The analyzed tomato puree is of satisfactory hygienic quality.

multi-variance ANOVA. The differences among treatments were verified by their least significant difference. Experiments were conducted in triplicate, mean values and standard deviation with different exponent letters are significantly at $p < 0.05$.

RESULTS

Microbiological characteristic of tomato purees

Pasteurization process was necessary to obtain products that could be preserved at room temperature for a long period. This heat treatment could permit to propose a simple process, easily transferable to local producers, to valorize local tomato varieties and to reduce losses during abundance period. With this objective, it is of high importance to evaluate the sanitary quality of the tomato puree obtained. The microbiological analyses made on the tomato purees produced in August and October revealed that the tomato purees after pasteurization were germ-free (Table 1, results obtained after 2 days of storage at 22 ± 1°C) and does not exceed the threshold values indicated by the regulation related of microbiological criteria of European Union. The analysis of total and thermotolerant coliforms did not reveal any colonies, whereas the standard tolerates 10 per gram of puree. As for the mesophilic aerobic flora, yeasts and molds, the analyses showed respectively less than 10 germs/g of puree. Puree tested did not contain any colonies of sulfite-reducing anaerobes (SRA) which are the germs responsible for deterioration of canned food at pH below 4.5. These results showed a good level of control of the parameters applied for pasteurization treatment. The process applied is effective and sufficient to stabilize the product during its duration of conservation.

Evaluation of conventional physicochemical parameters and nutritional compounds of fresh tomatoes and tomato puree

Local varieties of tomatoes (Aklikonvi, Tohounvi, and Pomvi) are not well characterized yet and the following results will help to bring knowledge related to physicochemical characteristics and the analysis of some specific compounds (two periods of harvest, August and October). Also, this study will help to understand the losses or evolution of the composition of the products related with the process applied in order to validate the final nutritional quality of the product.

First, different physico-chemical parameters (pH, °brix, titratable acidity, color) of the crushed tomato and tomato puree were done. Results are shown in Tables 2 to 4. pH values range between 4.10 and 4.42 for all varieties tested, pH<4.5. Whatever, the treatment and the month of production, there is little significant difference due to the general maturity of the tomatoes before processing into puree. Crushed tomatoes produced in August have a pH between 4.18 and 4.40, and their puree a pH ranging from 4.18 to 4.42. For October crushed tomatoes, we obtain a pH of 4.13 to 4.32 and for their puree a pH ranging from 4.12 to 4.31.

Soluble solids content values for all varieties range from 2.70 to 5.73%. Whatever the month of production, we observe an increase in the Brix degree during the transformation of the fresh tomato to the puree produced. Crushed tomatoes produced in August have a soluble solid content between 3.27 and 5.20, and their puree a pH ranging from 3.67 to 5.73. For October crushed tomatoes, we obtain a degree brix of 2.70 to 3.97 and for their puree a pH ranging from 4.40 to 5.53. The process of tomatoes into puree increases the brix degree of the tomatoes as revealed by the heat treatment. The total acidity of the tomatoes and purees produced expressed in citric acid equivalent (g/100 g) from our three varieties reveal a content of around 0.20 to 0.60%. The total acidity of the tomatoes and purees produced expressed in citric acid equivalent (g/100 g) from our three varieties reveal a content of around 0.20 to 0.60%.

Crushed tomatoes acidity produced in August range from 0.22 to 0.60, and their puree pH ranges from 0.24 to 0.55. For October crushed tomatoes, we obtain 0.21 to 0.37 for acidity value and for their titratable acidity it ranges from 0.31 to 0.62. The heat treatment increases the acidity of the purées whatever the variety.

As for color, the illuminant D65 in combination with the 10° CIE 1964 reference observer is commonly used. This

Table 2. Composition of acids and sugars of tomato varieties studied and purees.

Variety (p<0.05, IC=95%)	Month of production	Treatment	pH	Brix Degree (°B)	Total acidity (equivalent in citric acid g/100 g)	Glucose (mg/100 g)	Fructose (mg/100 g)
Aklikonvi	August	Crushed tomato	4.40 ± 0.02^{a}	3.67 ± 0.06^{d}	0.22 ± 0.01f	0.65 ±0.10^{f}	0.88 ± 0.13^{e}
		Puree	4.42 ± 0.03^{a}	4.00 ± 0.26^{d}	0.24 ± 0.02f	0.78 ± 0.09^{e}	1.07 ± 0.12^{d}
	October	Crushed tomato	4.28 ± 0.05^{c}	3.97 ± 0.21^{d}	0.33 ± 0.13^{e}	0.93 ± 0.04^{cd}	1.07 ± 0.04^{d}
		Puree	4.30 ± 0.01^{bc}	5.40 ± 0.30^{ab}	0.41 ± 0.05^{c}	1.21 ± 0.01^{b}	1.38 ± 0.01^{bc}
Tohounvi	August	Crushed tomato	4.20 ± 0.01^{d}	3.27 ± 0.06^{e}	0.42 ± 0.01^{c}	1.00 ± 0.03^{c}	1.33 ± 0.03^{c}
		Puree	4.30 ± 0.05^{bc}	3.67 ± 0.15^{d}	0.43 ± 0.20^{c}	1.01 ± 0.02^{c}	1.38 ± 0.02^{bc}
	October	Crushed tomato	4.13 ± 0.01^{e}	3.20 ± 0.44^{e}	0.37 ± 0.63^{d}	0.58 ± 0.02^{fg}	0.75 ± 0.03^{f}
		Puree	4.12 ± 0.01^{e}	5.53 ± 0.15^{ab}	0.62 ± 0.17^{a}	1.01 ± 0.01^{c}	1.29 ± 0.01^{c}
Pomvi	August	Crushed tomato	4.18 ± 0.01^{d}	5.20 ± 0.01^{b}	0.60 ± 0.02^{a}	1.22 ± 0.07^{b}	1.45 ± 0.01^{b}
		Puree	4.18 ± 0.01^{d}	5.73 ± 0.06^{a}	0.55 ± 0.01^{b}	1.52 ± 0.10^{a}	1.56 ± 0.10^{a}
	October	Crushed tomato	4.32 ± 0.01^{b}	2.70 ± 0.10f	0.21 ± 0.03f	0.54 ± 0.01^{g}	0.68 ± 0.02^{f}
		Puree	4.31 ± 0.01^{bc}	4.40 ± 0.26^{c}	0.31 ± 0.05^{e}	0.87 ± 0.02^{de}	1.07 ± 0.02^{d}

$^{a-e}$Different classes of crushed tomatoes and purees, the figures bearing different letters in the column are significantly different at the threshold of 0.05%.

Table 3. Color and Carotenoids content of tomato varieties studied and purees.

Variety (p<0.05, IC =95%)	Month of Production	Treatment	L	a	b	Ratio a/b	Lycopene (mg/100 g)	Beta-Carotene (mg/100 g)
Aklikonvi	August	Crushed tomato	25.33^{d}	12.37^{gh}	9.00^{d}	1.39 ± 0.14^{c}	2.46 ± 0.08^{e}	0.15 ± 0.01^{f}
		Puree	33.08^{c}	24.30^{de}	21.17^{bc}	1.15 ± 0.05 ^{def}	3.94 ± 0.21^{d}	0.27 ± 0.04^{de}
	October	Crushed tomato	28.57^{d}	16.56^{fg}	10.58^{d}	1.56 ± 0.04^{b}	4.44 ± 0.85^{cd}	0.18 ± 0.06^{ef}
		Puree	35.42^{bc}	30.92^{bc}	22.94^{ab}	1.34 ± 0.01^{c}	7.37 ± 0.45^{a}	0.49 ± 0.06^{ab}
Tohounvi	August	Crushed tomato	27.82^{d}	7.33^{h}	6.21^{d}	1.18 ± 0.02^{dc}	4.89 ± 0.04^{c}	0.51 ± 0.02^{ab}
		Puree	33.75^{c}	20.62^{ef}	19.69^{bc}	1.05 ± 0.03^{f}	5.96 ± 0.37^{b}	0.51 ± 0.03^{ab}
	October	Crushed tomato	32.99^{c}	28.37^{bcd}	16.59^{c}	1.72 ± 0.06^{a}	4.36 ± 0.61^{cd}	0.27 ± 0.05^{d}
		Puree	39.62^{a}	38.35^{a}	27.09^{a}	1.42 ± 0.02^{c}	7.09 ± 0.85^{a}	0.56 ± 0.08^{a}
Pomvi	August	Crushed tomato	27.94^{d}	12.03^{gh}	11.17^{d}	1.09 ± 0.11^{ef}	2.33 ± 0.10^{e}	0.23 ± 0.01^{de}
		Puree	34.67^{c}	21.33^{ef}	19.89^{bc}	1.07 ± 0.01^{ef}	4.61 ± 0.54^{cd}	0.39 ± 0.09^{c}
	October	Crushed tomato	35.71^{abc}	26.18^{cde}	19.22^{bc}	1.35 ± 0.09^{c}	3.02 ± 0.51^{e}	0.13 ± 0.03^{f}
		Puree	39.53^{ab}	33.34^{ab}	27.04^{a}	1.23 ± 0.04^{d}	6.85 ± 0.40^{a}	0.45 ± 0.02^{bc}

$^{a-e}$Different classes of crushed tomatoes and purees, the figures bearing different letters in the column are significantly different at the threshold of 0.05%.

was determined by ratio a/b determining the redness of our sample. The L fraction expresses the luminosity of the product; it remains related to the non-enzymatic browning reactions. The coordinates a*(red/green),

Table 4. Fibers content and Vitamin of tomato varieties studied and puree.

Variety (p<0.05, IC =95%)	Month of production	Treatment	Vitamin E (α-tocopherol; mg/100 g)	Fibers (g/100 g)
Aklikonvi	August	Crushed tomato	0.20 ± 0.01^{h}	1.63 ± 0.25^{cd}
		Puree	0.38 ± 0.02^{fg}	2.27 ± 0.10^{ab}
	October	Crushed tomato	0.45 ± 0.11^{ef}	0.97 ± 0.03^{g}
		Puree	1.08 ± 0.13^{ab}	1.76 ± 0.11^{fg}
Tohounvi	August	Crushed tomato	0.62 ± 0.05^{de}	1.52 ± 0.46^{a}
		Puree	0.79 ± 0.07^{cd}	1.58 ± 0.55^{de}
	October	Crushed tomato	0.40 ± 0.09^{fg}	1.53 ± 0.16^{def}
		Puree	0.93 ± 0.15^{bc}	2.09 ± 0.03^{bc}
Pomvi	August	Crushed tomato	0.64 ± 0.06^{d}	1.11 ± 0.17^{efg}
		Puree	1.14 ± 0.22^{a}	1.94 ± 0.63^{bcd}
	October	Crushed tomato	0.23 ± 0.09^{gh}	1.07 ± 0.08^{fg}
		Puree	0.93 ± 0.15^{bc}	1.94 ± 0.04^{bcd}

$^{a-e}$Different classes of crushed tomatoes and purees, the figures bearing different letters in the column are significantly different at the threshold of 0.05%.

b*(yellow/green) are directly correlated to the color values. As for color, the ratio a/b of crushed tomatoes produced in August varies between 1.09 and 1.39, and their puree has a ratio between 1.05 and 1.15. For crushed tomatoes produced in October, we obtain a ratio of 1.35 to 1.72 and for their puree a ratio ranging from 1.23 to 1.42 for all varieties. The ratio showed us that the heat treatment acts on the color of our tomatoes during cooking. The result in a low a/b value from crushed tomato to puree represented an orange to brown color due to the formation of Maillard reaction products by the intensive heat treatment.

The fiber content varies according to the month of cultivation. Crushed tomatoes produced in August have a fiber content of between 1.11 and 1.63 g/100 g, and their puree between 1.58 and 2.27 g/100 g. The crushed tomatoes produced in October have a fibers value of 0.97 to 1.53 g/100 g and for their puree values ranging from 1.76 to 2.09 g/100 g whatever the variety. Heat treatment of tomato puree increases the fiber content of our samples due to the concentration the product undergoes after cooking. For global analyses of all varieties, there was no statistically significant difference in the pH parameters, acidity; on the other hand, the effect of heat treatment (cooking) showed a significant difference in Brix degree, color (Table 2).

Then specific nutritional compounds were analyzed. All results obtained are in Tables 2 to 4 and are parallel with the results of the conventional analysis for further comparison.

Glucose and fructose and are the most common main sugars of the fruit. The values of crushed tomatoes in August showed a sugar content of 1.52 and 2.73%, and 1.85 to 3.30% for their puree. Crushed tomatoes produced in October have a sugar content of between 1.21 and 2.12 mg/100 g and their puree value of between 1.86 and 2.60 mg/100 g whatever the variety. Under the action of too much heating, fructose and glucose can be degraded in our purees. The sugar content of tomatoes varies due to the climatic and soil characteristics of each tomato variety and the presence or degradation of sucrose. This carbohydrate content may vary depending on different factors: light, temperature, irrigation and fertilizer.

The carotenoid composition of the tomato varieties studied reveals compounds with different levels of lycopene, carotenoids and vitamin E in Tables 3 and 4. Each variety vitamin E content values for all varieties range from 2.70 to 5.73%. Vitamin E content of crushed tomatoes produced in August is 0.20 to 0.64 mg/100 g and 0.38 to 1.14 mg/100 g for their puree. Vitamin E content values for crushed tomatoes produced in October range from 0.23 to 0.45 mg/100 g and pureed tomatoes range from 0.93 to 1.08 mg/100 g.

Beta-carotene results vary from 0.15 to 0.56 mg/100 g whatever the variety. The crushed tomatoes in August had a content of 0.15 to 0.51 mg/100 g and 0.38 to 1.14 mg/100 g for their puree.

Table 5. Phenols' composition of the tomato varieties and purees.

Variety (p<0.05, IC=95%)	Month of production	Treatment	Naringenin (µg/100 g)	Chlorogenic acid (µg/100 g)	Coumaric acid (µg/100 g)	Rutin (µg/100 g)
Aklikonvi	August	Crushed tomato	556.45 ± 68.88^{c}	466.76 ± 42.45^{e}	19.84 ± 2.98^{ef}	1420.85 ± 136.08^{bc}
		Puree	980.80 ± 142.22^{b}	1098.34 ± 43.35^{c}	33.97 ± 3.93^{c}	1548.60 ± 45.90^{b}
	October	Crushed tomato	101.18 ± 14.32^{de}	287.24 ± 10.30^{f}	9.13 ± 1.20^{hi}	1283.07 ± 46.76^{cd}
		Puree	134.39 ± 7.41^{d}	472.03 ± 74.40^{e}	10.31 ± 1.11^{ghi}	1460.76 ± 197.90^{b}
Tohounvi	August	Crushed tomato	924.50 ± 25.27^{b}	2100.95 ± 53.71^{a}	67.86 ± 0.47^{a}	1157.41 ± 22.36^{d}
		Puree	1022.22 ± 50.80^{b}	2146.54 ± 117.81^{a}	54.81 ± 0.87^{b}	1316.18 ± 31.98^{c}
	October	Crushed tomato	82.23 ± 18.50 ^{e}	542.08 ± 150.28^{b}	16.78 ± 5.25^{efg}	208.05 ± 3.12^{g}
		Puree	98.49 ± 3.38 de	1671.60 ± 42.14^{b}	20.64 ± 1.81^{de}	447.71 ± 6.42^{fg}
Pomvi	August	Crushed tomato	1305 ± 109.61^{a}	940.40 ± 35.35^{d}	25.77 ± 7.25^{d}	2404.27 ± 79.24^{a}
		Puree	173.99 ± 14.39^{d}	512.83 ± 150.52^{e}	15.85 ± 5.53^{ef}	621.70 ± 15.17^{e}
	October	Crushed tomato	10.33 ± 3.18^{f}	82.44 ± 0.41^{g}	14.37 ± 0.41^{fgh}	453.27 ± 9.30f^{g}
		Puree	111.03 ± 6.89^{de}	342.05 ± 3.91^{f}	6.60 ± 0.67^{i}	537.46 ± 7.82^{f}

$^{a-e}$Different classes of crushed tomatoes and purees, the figures bearing different letters in the column are significantly different at the threshold of 0.05%.

Lycopene, the most abundant antioxidant in tomatoes, reveals its different levels in the three varieties studied. The month of August produced crushed tomatoes with a lycopene content of 2.33 to 5.01 mg/100 g and 3.94 to 4.60 mg/100 g of puree. Crushed tomatoes produced in October have a lycopene content of 3.02 to 4.44 mg/100 g and a value of 6.85 to 7.36 mg/100 g for their puree for each variety. There is a significant difference in carotenoids due to the effect of the heat treatment (cooking). As a result, purees have higher carotenoids content than crushed tomatoes and extended thermal heating can degrade carotenoids.

The results for phenolic compounds are shown in Table 5. For all varieties, values of 0.55 to 4.66 mg/100 g of total polyphenol content measured are obtained.

In August, crushed tomatoes gave us a total phenolic compound content of 2.47 to 4.66 mg/100 g and 1.29 to 3.66 mg/100 g for purees. Crushed tomatoes produced in October have a polyphenol content of 0.55 to 1.68 mg/100 g and a value of 0.99 to 2.10 mg/100 g for their puree. Differences found between tomato varieties depend on the month of cultivation of the tomatoes. This can be explained by the strong dependence of various factors, such as maturity, variety and agronomic conditions of the nutritional content of our tomatoes.

DISCUSSION

The evaluation of the hygienic quality of the different products showed a satisfactory result in relation to the European Union's microbiological criteria (2007). This can be explained by the respect of good manufacturing practices during our production with a pasteurization scale (75°C at 30 min) applied to canned products with a pH lower than 4.5. Dossou et al. (2007) obtained similar results. In their studies, the analysis of fecal coliforms and total coliforms on their purees revealed no germ, whereas the standard tolerates 10 g^{-1} of puree.

As for their total germs and the yeasts and molds, the analysis revealed respectively less than 30 microorganisms/g of puree, against 300 g^{-1} of product, tolerated by the standard. This indicates a good level of hygiene in the production of the puree. The pH of the puree between 4 and 4.5 significantly reduces the rate and range of microorganisms that can grow on the product. Only acidophilic microorganisms, including yeasts and moulds and lactobacilli, can grow. This result corroborates those of studies conducted in Benin which also revealed an acidic pH (4.01 - 4.17) in processed tomatoes (Dossou et al., 2007).

A pH of 4 to 4.4 was found for our crushed tomatoes and purees studied. Oboulbiga et al. (2017) found values slightly lower than ours, ranging from 3.71 to 4.08 and 3.70 to 4.1 for Fagbohoun and Kiki (2000). As for the titratable acidity of the products, the significant variations observed between varieties could be due to soil and climate characteristics (Fagbohoun and Kiki, 1999). Adsule (2006) found in his studies that round tomato varieties have an acidity rate between 0.42 and 0.75%

and those with elongated shape have a rate of 0.36 to 0.45%. The titratable acidity of our crushed tomatoes and purees reveals semilar results to those found by Adsule. Our round ribbed tomato varieties (Tohounvi) have an acidity of 0.42 to 0.62 citric acid equivalent and 0.22 to 0.42 citric acid equivalent for our elongated tomatoes (Aklikonvi). Brix results of purees being higher than those of crushed tomatoes could be explained by the heat treatment of tomato during cooking but production in different seasons does not affect the three varieties.

Brix degree values found ranging from 2.70 to 5.73% corroborate the results of the work carried out by Helyes et al. (2006) which obtained values of 4 to 5.5% and 4.5 to 5% from Dossou et al. (2007). The variation of the Brix value goes in the downward direction. Brix is more affected as the temperature of the treatment is higher. Brix being a key parameter of the quality of the concentrated, its decline is interpreted as a decrease quality of the concentrate according to Boumendjel et al. (2012). Brix being a key parameter of concentrate quality, its increase would be interpreted as good product quality in our case.

Aklikonvi purees have a better color compared to the other two varieties. Moreover, the results showed that a/b ratio is the appropriate parameter to characterize the degree of ripeness of tomato fruits. Helyes et al. (2006) obtained a value for a/b ratio between 0.5 and 1.5; Diantom et al. (2017) obtained values between 1.07 and 1.10. Jacob et al. (2010) obtained values between 0.68 and 1.11.

Results found for a/b ratio fall within the range of values obtained by the authors cited. The difference in color between the crushed tomato and the puree is due to the heat treatment that crushed tomatoes undergo when cooked for 20 min at 100°C. Boumendjel et al. (2012) had noticed that the color is more affected by the time of exposure to heat than the temperature of the treatment. The color being a technological parameter, its variation does not affect the commercial quality. The values obtained for total fiber ranging from 0.97 to 2.73 g/100 g for crushed tomatoes and purees are in the same range as the fiber content measured in Diantom et al. (2017) who found a content of 1.5 g of fiber in their puree.

The total sugar content of our different samples is 1.21 to 3.30 g/100 g. These results corroborate with those found by some authors who have worked in Benin, Nigeria and Italy. Akinboye et al. (2018) obtained values between 2.48 and 3.05 g/100 g. Helyes et al. (2013) also found a value of 2 to 3 g/100 g for the sugar content. Fagbohoun and Kiki (2000) found 1.97 and 3.1 g/100 g.

Lycopene is a particularly effective antioxidant capable of combating free radicals much more effectively than beta-carotene. Crushed tomatoes and tomato puree are high in lycopene, which is an advantage for the consumer because it is the main pigment in tomatoes that indicates the maturity of the fruit and contributes to the prevention of various forms of cancer (Agarwal et al., 2000). The analysis on crushed tomatoes and puree reveals a lycopene content of 2.33 to 7.37 mg/100 g and a beta-carotene content of 0.13 to 0.56 mg/100 g of product. Georgé et al. (2011) obtained a lycopene concentration of 3.7 mg/100 g and a beta-carotene concentration of 1.1 mg/100 g. Akinboye et al. (2018) obtained for the studied tomato varieties a content of 2.61 to 2.75 mg/100 g lycopene and 0.43 to 0.44 mg/100 g beta carotene. The vitamin E or α-tocopherol content on the crushed tomatoes and puree allowed us to obtain a content of 0.20 to 1.18 mg/100 g of fresh fruit. These results are in line with values found by Grasselly et al. (2000) ranging from 0.04 to 1.20 mg/100 g of vitamin E.

The main phenolic compounds in tomatoes are rutin, chlorogenic acid and naringenin, which are considered antioxidants with a beneficial effect on human health. The amount of phenolic antioxidants in processed tomatoes is higher than in raw tomatoes (Chanforan, 2010).

Our results reveal rutin contents of 0.20 to 2.40 mg/100 g, chlorogenic acid of 0.08 to 1.67 mg/100 g, naringenin of 0.009 to 1.30 mg/100 g and 0.006 to 0.06 mg/100 g of coumaric acid. Values are close to those of Jacob et al. (2010) who obtained a content of 0.09 to 1.73 mg/100 g chlorogenic acid, 0.08 to 2.12 mg/100 g rutin and 0.13 to 0.33 mg/100 g coumaric acid.

Conclusion

At the end of this study, tomato purees were made from three tomato varieties produced in Togo: Pomvi, Aklikonvi and Tohounvi. These tomatoes have proven to be good sources of nutritional content. The physico-chemical characteristics as well as the microbiological quality of these purées were determined. The purees show microbiological stability. The results of the various analyses show the usefulness of the transformation of crushed tomatoes into puree in a small-scale local context.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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