

Nutritional composition and antioxidant capacity of four tomato varieties (*Lycopersicon esculentum* Mill) cultivated in Cote d'Ivoire.

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Abstract

Aims: This study is to ascertain nutrient content and antioxidant compounds of four varieties of *Lycopersicon esculentum* Mill. (*UC82b*, *Amiral F1*, *Local cotelette* and *Local cerise*) grown in Cote d'Ivoire.

Study design: This study is to assess the nutritional and antioxidant value of tomatoes (*Lycopersicon esculentum* Mill.) grown in Cote d'Ivoire in order to know if they can help to prevent against oxidative stress.

Place and duration of study: Four ripe tomato varieties were collected from different tomato fields in Yamoussoukro district (Cote d'Ivoire) during season from December 2016 to January 2017. The determination of nutrient content and antioxidant compounds were ascertained at the LAPISEN of INPHB (Yamoussoukro).

Methodology: Macronutrient and micronutrient of the four tomato varieties collected were determinate. Then, lycopene, polyphenol and flavonoid contents were assessed. The antioxidant capacity of tomato extracts was evaluated using DPPH method.

Results: Among the varieties studied, *Amiral F1* has the highest antioxidant capacity with an EC₅₀ of 3.47 mg/mL and the highest total polyphenol content (17.5 mg/100 g EAG of fw). *Local cotelette* variety is the richest in lycopene (2.9 mg/100 g of fw) and vitamin C (35.4 mg/100 g of fw). In addition, this variety also has the highest levels of calcium (31 mg/100 g of fw), magnesium (21 mg/100 g of fw) and potassium (333 mg/100 g of fw). *UC82b* is the best source of iron (0.065 mg/100 g of fw), phosphorus (23 mg/100 g of fw), manganese (0.086 mg /100 g of fw) and zinc (0.11 mg/100 g of fw).

Conclusion: This investigation showed that the different studied varieties of tomato possessed high antioxidant capacities. As a result, they could be used to fight against oxidative stress.

Key words: Antioxydant activity, lycopene, total polyphenols, tomato varieties.

1 Introduction

Lycopersicon esculentum Mill commonly known as tomato is from Northwestern of South America. It has been considered a long time like an ornamental plant. Today, tomatoes are among fruit-vegetables which are most consumed in the world. It is the third most cultivated species in the world after potatoes and sweet potatoes [1]. In addition, it is the second most consumed fruit-vegetable in the world after potatoes [2].

Tomatoes present different colors depending on their stage of maturity (green, yellow, orange or red). Their red color indicates the full maturity stage. This coloring is due to carotenoids synthesized during its maturation [3]. The main carotenoid responsible for this coloring is lycopene, which contains a very powerful antioxidant [4]. Lycopene is only brought to body by food [5].

According to Giovannucci [6], the high consumption of lycopene or tomato products protect people against prostate cancer. Also, there are a correlation between tomatoes consumption or tomato-based foods and diseases reduction such as cardiovascular diseases, gastrointestinal infections and epithelial cell infections [7, 8]. This would be due to antioxidant compounds found in tomatoes such as vitamins C and E, flavonoids and other phenolic compounds [9]. Other studies have highlighted nutritional and antioxidant properties of tomatoes [10, 11, 12]. However, little scientific data are available for tomatoes from Cote d'Ivoire. So, various conditions such as the climate, soil type, variety and maturity stage can influence the physicochemical, antioxidant and nutritional composition of plant's fruits [13, 14]. Thus, the present study focused about determination of the nutritional value and antioxidant capacity of four varieties of tomato grown in Cote d'Ivoire. They will determine macronutrient (carbohydrates, lipids and proteins), micronutrient, oligo nutrient contents, antioxidant compounds and evaluate the antioxidant activity of these varieties.

2 Material and methods

2.1 Material

2.1.1 Plant material

Three local varieties of tomato (*UC82b*, *Locale cerise* and *Locale cotelette*) and one hybrid variety of tomato called *Amiral FI* were used for this study (Figure 1). These different

varieties were harvested from three different farmers in Yamoussoukro district, namely N'gattakro, Zatta and Lolobo, from the Central of Cote d'Ivoire.

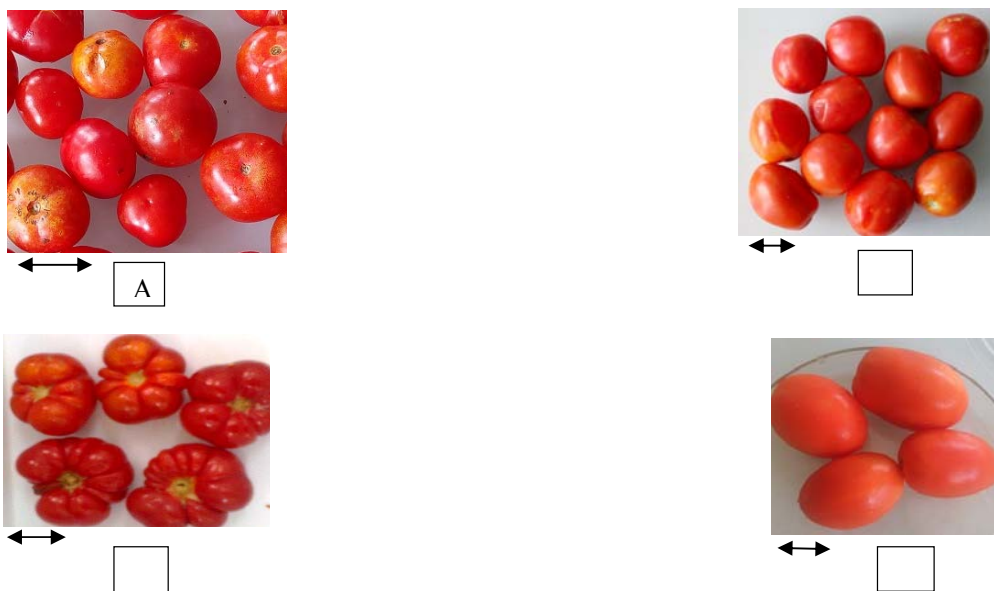


Figure 1: Different varieties of tomato *Lycopersicon esculentum* Mill.
A: Local cerise, B: UC82b, C: Local cotelette, D: Amiral F1 (hybrid)

2.1.2 Chemicals

All chemicals used were analytical quality. Methanol (Carlo Erba, Spain), Folin-Ciocalteu reagent (Panreac quimica, Spain), sodium nitrite (Merck, Germany), calcium carbonate (Merck, Germany), aluminum chloride (Merck, Germany), sodium hydroxide (Scharlau, Spain), citric acid (Riedel-of-Haën, Germany), ethanol (Carlo Erba, Spain), acetone (Carlo Erba, Spain), hydrochloric acid (Panreac quimica, Spain), sulfuric acid 96 % (Carlo Erba, Spain). Standards used for polyphenols quantification were gallic acid (Sigma Aldrich, Germany) for total polyphenols and quercetin (Sigma-Aldrich, Germany) for total flavonoids. Standard multi element solution was used to characterize trace elements (Tecknolab AB, Sweden). DPPH (1,1-diphenyl-2-picryl-hydrazyl) for antioxidant activity assessment and β -carotene for carotenoids characterization were from Fluka (USA)

2.2 Methods

2.2.1 Sampling

Samples were performed during the period from December 2016 to January 2017. They concerned firm fruits at commercial maturity stage (red color). The fruits were kept in coolers containing ice and then sent to the laboratory. Then, the collected samples were gathered by

variety and divided into two parts. The first part was dried at 60 °C for 48 hours and then milled and the second part refrigerated at 4°C.

2.2.2 Preparation of ethanolic extract

Dried sample was ground and then 10 g of the ground material were homogenized in 100 mL of 70 % (V / V) ethanol for 24 hours. The mixture was centrifuged at 1000 rpm for 10 min. The supernatant was recovered and dried at 60°C for 48 hours. After, extracts were used to determinate total polyphenols, total flavonoids and antioxidant activity of various tomatoes.

2.2.3 Determination of physicochemical parameters

Moisture content, ash content, dry matter, titratable acidity and pH were determined according to AOAC method [15].

2.2.4 Determination of macronutrient content

Crude fiber and total protein measurements extracted by Kjeldahl were determined using AOAC method [15]. In addition, total lipid content extracted by Soxhlet was determined according to AFNOR method [16]. Finally, total carbohydrate content was determined according to FAO method [17] using following formula:

$$\text{Total Carbohydrates (\%)} = 100 - [(\% \text{ Protein}) + (\% \text{ Lipid}) + (\% \text{ Water}) + (\% \text{ Ashes})]$$

2.2.5 Determination of energy value

Total energy value was determined according to FAO method [17] using following formula.

$$\text{Energy Value (Kcal / 100g fw)} = (\% \text{ protein} \times 4) + (\% \text{ lipid} \times 9) + (\% \text{ carbohydrate} \times 4)$$

2.2.6 Determination of mineral content

Minerals such as calcium, iron, magnesium, phosphorus, potassium, manganese and zinc were assayed by an atomic absorption flame spectrophotometer (Varian AA Spectrometer, Australia). Mineral contents of the different varieties of tomatoes were determined according to AOAC method by the calibration line of each desired mineral.

2.2.7 Determination of vitamin C content

Vitamin C content was determined according to Pelletier *et al* [18] method. 10 grams of fresh cut tomatoes were crushed and solubilized in 40 mL of meta phosphoric acid (2 %). The whole was then subjected to centrifugation at 3000 rpm for 20 minutes. The supernatant obtained was adjusted with distilled water to 50 mL. 10 mL of this solution was titrated with a solution of 2.6 DCPIP at 0.5 g / L until turning pink (pink champagne). Vitamin C content

was determined as follow:

$$\text{Vitamin C (\%)} = \frac{(0,5 \times v \times 10^3 \times 500)}{m_e}$$

With :

v: 2,6 DCPIP volume poured in equivalence

m_e : the test sample

2.2.8 Determination of total carotenoid content

Carotenoid content was determined according to FAO method [17]. 2 g of fresh tomatoes were crushed and homogenized in 50 mL of acetone until complete decolorization of the residue. The filtrates were introduced into a separating funnel and 100 mL of petroleum ether were added. The mixture was stirred slightly and then leaving at rest. The ether phase (phase containing carotenoids) was recovered in another bulb, washed with 50 mL of distilled water and then dried with 10 g of anhydrous sodium sulphate. Absorbance of this solution was read spectrophotometer at 450 nm against petroleum ether. Carotenoid content was determined according to a calibration line in β -carotene equivalent per gram of fresh crude.

2.2.9 Determination of lycopene content

Lycopene was measured in tomatoes according to method described by Benakmoom *et al* [19]. 0.1 g of tomato powder was dissolved in 10 mL of solvent mixture (hexane / acetone / ethanol, 50/50/1, V / V / V) and then stirred for 10 min. The whole was centrifuged at 5000 rpm for 15 minutes. Then, 1 mL of the organic phase was recovered and diluted in 10 mL of hexane. Absorbance of this solution was measured at 472 nm using hexane as blank. Lycopene content was determined according to the following formula :

$$\text{Lycopene content (\%)} = \frac{(\text{Abs}_{472} \times \text{Fd} \times 10^5 \times \text{V})}{3450 \times 100 \times \text{m}}$$

Fd: Dilution factor

V: Volume of extraction solvent,

3450: Extinguishing coefficient of hexane,

m: Weight of the test sample.

2.2.10 Determination of total polyphenols in tomatoes

To 2.5 mL of Folin-Ciocalteu reagent diluted 1/10 were added 30 μ L of diluted extract of tomato. The mixture was kept for 2 min in dark at room temperature (30 ± 2 ° C). 2 mL of

Na_2CO_3 (75 gL^{-1}) was added. The resulting mixture was incubated at $50 \text{ }^\circ\text{C}$ in a water bath during 15 minutes in order to allow total development of the blue color. The absorbance was read to UV-visible spectrophotometer at wavelength $\lambda = 760 \text{ nm}$. Polyphenols assayed was expressed as mg EAG (Equivalent Gallic Acid) per g of dry plant extracted according to Singleton and Wood method [20, 21]. Assays were performed in triplicate.

2.2.11 Determination of total flavonoids in tomatoes

Total flavonoid assay was performed according to the method described by Marinova *et al.* [22]. 2.5 mL of diluted extract was mixed with 0.75 mL of 5 % (w/v) NaNO_2 and 0.75 mL of 10 % (w/v) AlCl_3 . After 6 min of reaction in dark at room temperature ($30 \pm 2 \text{ }^\circ\text{C}$), 5 mL of NaOH (1 M) were added to the mixture. The volume of the mixture was adjusted to 25 mL with distilled water and it was agitated vigorously. Absorbance of the solution was measured with spectrophotometric at $\lambda = 510 \text{ nm}$. Total flavonoid assayed was expressed as mg QE (Equivalent Quercetin) per g of dried plant extract. All assays were performed in triplicate.

2.2.12 Determination of the antioxidant activity of tomatoes by the DPPH method

The antioxidant activity of tomatoes was determined according to the method described by Von gadow [23]. The inhibition percentage of DPPH by tomato extracts and their efficacy concentration at 50 % (EC_{50}) were performed. 50 μL of ethanolic extract from different concentrations (1 to 10 mg.mL^{-1}), 5 mL of methanolic DPPH at 25 mg.L^{-1} were added. The mixture was incubated at room temperature without light for 30 minutes. Absorbance was read at 515 nm relative to methanol. About the control, 50 μL of of ethanolic extract was replaced by 50 μL of methanol. Inhibition percentage (% inh) of ethanolic extracts of tomato was determined as follows:

$$\% \text{ Inhibition} = \frac{(A_0 - A_{30}) \times 100}{A_0}$$

With:

A_0 : absorbance of control after 30 min of incubation,

A_{30} : absorbance of sample after 30 min of incubation.

The efficient concentration at 50 % DPPH of the different extracts was determined according to the line $f(C) = \% \text{ inhibition}$. It has been determinate as follows:

$$\text{EC}_{50} = \frac{(50 - b)}{a}$$

a: directing coefficient of the line, **f(C)** : % inhibition, **b** : y-intercept

Statistical analysis

Statistical analysis was carried out by performing a one-way variances analysis (1-factor ANOVA) for all data (mean of each metered parameter). This analysis was performed using Statistica 7.1 software. Mean comparisons were made by the Newman-Keuls test at $p < 0.05$.

3 Results

3.1 Physicochemical parameters of tomatoes

Table 1 shows physicochemical parameter of four varieties of tomato (*UC82b*, *Amiral F1*, *Local cotelette* and *Local cerise*) grown in Cote d'Ivoire. Water contents of studied tomatoes are all greater than 91 %. Ash levels determined for these tomatoes vary between 0.5 and 0.8 %. In ascending order, ash rate of variety *UC82b* < *Amiral F1* < *local cerise* < *Local cotelette*. pH of these tomatoes varies from 3.6 to 4.1. *Local cerise* variety has the lowest pH (pH = 3.6) while *Amiral F1* variety has the highest pH (pH = 4.1). In ascending order of pH: pH (*local cerise*) < pH (*local cotelette*) < pH (*UC82b*) < pH (*Amiral F1*).

3.2 Nutritional composition

3.2.1 Macronutrient content and energy value

Table 2 shows total protein, total carbohydrate, total lipid, fiber and energy value of four varieties of tomato (*UC82b*, *Amiral F1*, *Local cotelette* and *Local cerise*) grown in Cote d'Ivoire. Total protein content of the four tomatoes varieties ranges from 0.74 to 1.46 g per 100 g of fresh tomatoes. Among studied tomatoes, *Local cotelette* variety has the highest protein content. In contrast, *UC82b* variety contains the small amount of protein. However, statistical analyzes showed that there is no significant ($p > 0.05$) difference between protein content of *Amiral F1* and *UC82b* varieties.

Total lipid content of these tomatoes ranges from 0.05 to 0.79 g per 100 g of fresh tomatoes. Results analysis showed that *Local cerise* variety is the richest in lipid and variety *UC82b*, the least rich in lipid. The results also indicate that *Local cerise* variety is the richest carbohydrate (5.58 g/100 g of fresh tomato). In contrast, *Amiral F1* variety has the lowest carbohydrate content (3.48 g/100 g fresh tomato). Carbohydrate content of *Local cerise* is higher than that of *Amiral F1*, but this difference is not significative at ($p > 0.05$).

Fiber content of the four varieties of tomato is ranging between 0.7 and 2 g per 100 g of fresh tomatoes. *Local cotelette* variety has the highest fiber content and *Amiral F1* variety has the lowest fiber content.

Energy value of these four varieties of tomato ranges from 18 to 32 kilocalories per 100 g fresh tomatoes. *Local cotelette* variety has the highest energy value. *Amiral FI* variety has the lowest energy value. In ascending order of energy value, we have energy value (*Amiral FI*) < energy value (*UC82b*) < energy value (*Local cerise*) < energy value (*Local cotelette*).

3.2.2 Micronutrient contents

Various mineral contents (Calcium, Iron, Magnesium, Phosphorus, Potassium, Manganese and Zinc) of four varieties of tomato grown in Cote d'Ivoire (*UC82b*, *Amiral FI*, *Local cotelette* and *Local cerise*) are summarized in Table 3. They present varying proportions of minerals such as calcium, iron, magnesium, phosphorus, potassium, manganese and zinc. Among those, *Local cotelette* is the richest in calcium (31 mg), magnesium (21 mg) and potassium (332.6 mg) while *UC82b* is the best source of zinc (0.11 mg) and phosphorus (22.62 mg). However, iron and manganese contents of the four varieties of tomato are not significantly different at $p < 0.05$.

3.3 Antioxidant compound contents

Antioxidant compounds content (vitamin C, carotenoid, lycopene, total polyphenols and total flavonoids) of four varieties of tomato (*UC82b*, *Amiral FI*, *Local cotelette* and *Local cerise*) grown in Cote d'Ivoire are given in Table 4. Vitamin C content of four studied varieties of tomato ranges from 9 to 35.4 mg per 100 g of fresh tomato. *Local cotelette* variety is the richest in vitamin C while *Amiral FI* variety is the least rich in vitamin C. Carotenoid content of four varieties of tomato varies from 13 to 21.6 mg equivalent β -carotene per 100 g of fresh tomato. *UC82b* variety has the highest carotenoid content while *Amiral FI* variety has the lowest carotenoid content. Statistical analyzes showed that there was no significant difference at $p < 0.05$ between carotenoid contents of *Local cerise* and *Local cotelette* varieties. Lycopene content of four varieties of tomato ranges from 1.7 to 2.9 mg per 100 g of fresh tomato. *Local cotelette* variety has the highest lycopene content (2.9 mg). In contrast, *Amiral FI* variety has the lowest lycopene content (1.7 mg). Classification from the lowest to the highest lycopene content is as follows: *Amiral FI* (1.7 mg) < *UC82b* (2.04 mg) < *Local cerise* (2.15 mg) < *Local cotelette* (2.95 mg). However, statistical analyzes showed that lycopene levels of *UC82b* and *Local cerise* varieties are not significantly different at $p < 0.05$. Total polyphenol content of four varieties of tomato ranges from 13 to 17.5 mg/100 g EAG of fresh tomato. *Amiral FI* variety contains the highest polyphenol content and *Local cerise* variety has the lowest polyphenol content. However, *Local cotelette* and *UC82b* polyphenol content does not show a significant difference at $p < 0.05$.

Total flavonoid content of the four varieties of tomato ranges from 2 to 3.1 mg/100 g quercetin equivalent of fresh tomato. Flavonoid level is highest in *Local cerise* variety (3.1 mg) whereas *UC82b* variety (1.98 mg) has the lowest flavonoid content. Flavonoid content of the different varieties of tomato in ascending order is as follows: *UC82b* (1.98 mg) < *Local cotelette* (2.5 mg) < *Amiral F1* (2.6 mg) < *Local cerise* (3, 1 mg). Statistical analyzes have also shown that there is no significant difference between flavonoid content of *Amiral F1* and *Local cotelette* varieties at $p < 0.05$.

3.4 Antioxidant activity of different varieties of tomato

Table 5 shows antioxidant activity of four varieties of tomato grown in Cote d'Ivoire (*UC82b*, *Amiral F1*, *Local cotelette* and *Local cerise*) using efficient concentration at 50 % (CE₅₀). CE₅₀ of different varieties of tomato is ranged between 3.47 and 6.74 mg / mL of extract. It represents the amount of the extract which can reduce the DPPH radical at 50%. So, when the inhibitory concentration is low, the antioxidant capacity of the extract is higher. In descending order, *Local cerise* variety has the highest efficient concentration at 50 % and then *UC82b*, *Local cotelette* and *Amiral F1*. The antioxidant activity is as follows: *Amiral F1* > *Local cotelette* > *UC82b* > *Local cerise*. These varieties of tomato have lower antioxidant power than vitamin C.

Discussion

Abundant presence of water in food promotes growth of several micro-organisms (other bacteria, yeasts and molds) [25]. The high perishability of tomatoes is due to this high water content. It causes difficulties in their conservation. However, acidity of these tomatoes could inhibit most of microorganisms which can deteriorate them except for acidophilic bacteria, yeasts and molds [26].

Ash content of various analyzed tomatoes is similar to those reported by Guil-Guerrero and Reboloso-Fuentes [27] and Pinela *et al.* [28] who obtained ash levels of their studied tomatoes ranging from 0.6 to 1.4 %. Existence of these ashes is a presumption of minerals presence in these different varieties. Protein, lipid and carbohydrate composition of these tomatoes also is close to those obtained by these same authors [28]; [27] except for *Local cerise* variety, which has a lipid content of 0.79 %. This high lipid content of *Local cerise* may be due to the fact that climatic, environmental, maturity and tomato variety conditions significantly influence tomatoes nutrient content [14].

Micronutrient content of four varieties of tomato is close to that of tomatoes studied by Halevy *et al.* [29], Guil-Guerrero and Reboloso-Fuentes [27]. These micronutrients vary

slightly from one variety to another. These minerals are very important to prevent against several pathologies. Indeed, zinc and manganese can fight against inflammatory diseases [30]. They also promote the trapping of free radicals [31]. Potassium contributes to regulate arterial blood pressure [32, 33]. Houston and Whelton have shown that 4700 mg by day of potassium supplementation will decrease arterial blood pressure from 4.4 to 2.5 mmHg. However, calcium has anti carcinogenic activity because it reduces colorectal cancer risk [34]. So with phosphorus, calcium can help to fight osteoporosis which is the weakening of bones due to calcium deficiency [35]. Magnesium is an enzymatic cofactor which limits conversion of linoleic acid to γ -linolenic acid. This latter may contribute to prostaglandin synthesis (substances causing brain disorders) [36, 37].

If minerals are bioavailable, consumption of these different varieties of tomato could prevent hypertension, cancer and oxidative stress by trapping free radicals.

Among analyzed varieties, only vitamin C content of *UC82b* variety (20.34 mg) is similar to those obtained by Halevy *et al.*, [29] and Raffo *et al.*, [38] which have a content ranging between 11 and 21 mg per 100 g of fresh tomato. Vitamin C contents of *Local cerise* (31.64 mg) and *Local cotelette* (35.4 mg) varieties are higher than this value. Also, *Amiral F1* variety which has a vitamin C content of 9 mg is lower compared to this value. These differences in vitamin C content between varieties may be due to the degree of maturity or the post-harvest conservation technique [38]. The presence of vitamin C in these tomatoes could be beneficial for consumer because it inhibits free radicals 'production and reduces oxidative stress [39]. In addition, it helps to regulate insulin levels about diabetic patients [40, 41].

The α -carotene, β -carotene, β -cryptoxanthin, lycopene and many other carotenoids are responsible for tomatoes red color [42, 43]. These compounds are mostly pro-vitamin A and also powerful antioxidants. Therefore, presence of these compounds in these tomatoes could help consumer to fight against vitamin A deficiency. Moreover, these compounds could reduce oxidative stress by the trapping of free radicals. Lycopene levels of various analyzed tomatoes is similar to those obtained by Schierle *et al.* [44] and Gross [45]. These authors are obtained a lycopene content ranging between 0.88 and 4.2 mg per 100 g of fresh tomato. Lycopene is the main carotenoid of tomatoes [4]. It contributes to the red coloring of tomatoes [3]. It has best antioxidant properties. It is very important about trapping of free radicals [24]. It's because tomatoes get the strong antioxidant power.

Polyphenol contents determined in tomatoes are lower than those obtained by Pinela *et al.*, (2012) which are ranging between 21.34 and 31.23 mg/100 g EAG. This difference in polyphenol content may be due to either tomato variety, tomato maturity stage or agronomic

and environmental conditions during cultivation as described by Abushita *et al*, [46], Binoy *et al*, [47], Leonardi [48] and Strazzullo [49]. However, phenolic compounds extracting procedure can influence phenolic compounds content [50]; [51].

Antioxidant compound of tomatoes can be hydrophilic or lipophilic. The hydrophilic fraction is vitamin C and phenolic compounds. Lipophilic fraction is carotenoids and vitamin E. These antioxidant compounds in tomatoes interact synergistically to prevent oxidative stress and contribute to health [52]; [53]; [48]. *Amiral F1* variety has the highest antioxidant power and the highest level of total polyphenols. These results confirm the strong antioxidant properties of phenolic compounds [54, 55]. Obrenovich *et al*. [56] showed a strong impact of phenolic compounds on cancer risks and chronic diseases reduction.

5 Conclusion

This study showed that nutrient composition, antioxidant compounds and antioxidant capacity depend to variety. Among studied varieties of tomato, *Amiral F1* has the best profile because it has the lowest energy value and the strongest antioxidant power. All of these varieties are good sources of micronutrients. Their consumption can thus make it possible to fight against deficiency of these nutrients. In addition, the presence of antioxidant compounds such as vitamin C, polyphenols and lycopene in these tomatoes could make them a real source of antioxidant. So, their regular consumption can help to fight against oxidative stress.

Authors' Contributions

This work was carried out in collaboration between all authors. Author SD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors' ENK, IC, AAA, KY and AAAL managed the study and the literature searches. All authors read and approved the final manuscript.

6. Références bibliographiques

- [1] DeBroglie and D. Guérault. Tomates d'hier et d'aujourd'hui. 2005.
- [2] FAOSTAT. Organisation des nations unies pour l'alimentation et l'agriculture. <http://faostat.fao.org/>. 2013.
- [3] Zeb A, Mehmood S. Carotenoids contents from various sources and their potential health applications. Pakistan Journal of Nutrition. 2004, 3: pp. 199-204.
- [4] Rao and Agarwal. S, Role of lycopene as antioxidant carotenoid in the prevention of chronic diseases: A review. Nutrition Research. 1999, 19(2): pp. 305-323.

- [5] Clinton SK. Lycopene: Chemistry, biology, and implications for human health and disease. *Nutr Rev.* 1998, 56(2), pp.35.
- [6] Giovannucci E, Rimm EB, Liu Y, Stampfer MJ, Willett WC. A prospective study of tomato products, lycopene, and prostate cancer risk. *J. Natl. Cancer Inst.* 2002, 94: pp. 391-398.
- [7] Agarwal S, Rao A. Tomato lycopene and its role in human health and chronic diseases. *Can Med Am J.* 2000, pp.163:739.
- [8] Rao AV, Rao LG. Carotenoids and human health. *Pharmacological Research.* 2007, 55: pp. 207-216,
- [9] Lenucci MS, Cadinu D, Taurino M, Piro G, Dalessandro G, Antioxidant composition in cherry and high-pigment tomato cultivars. *Journal of Agricultural and Food Chemistry.* 2006, 54: pp. 2606-2613.
- [10] Gautier VD, Verdin C, Bénard M, Reich M, Buret F, Bourgaud JL, Poessel C, Caris-Veyrat, Génard M. How does tomato quality (sugar, acid, and nutritional quality) vary with ripening stage, temperature, and irradiance? *J. Agric. Food Chem.* 2008, 56: pp. 1241-1250.
- [11] Ilahy R, Hdider C, Lenucci MS, Tlili I, Dalessandro G. *Phytochemical composition and antioxidant activity of high-lycopene tomato (Solanum lycopersicum L.) cultivars grown in Southern Italy.* *Sci. Hort.* 2011, 127: pp. 255-261.
- [12] Kotkov Z, Lachman J, Hejtmnkov, A, Hejtmnkov K, Determination of antioxidant activity and antioxidant content in tomato varieties and evaluation of mutual interactions between antioxidants. *LWT - Food Sci. Technol.* 2011, 44: pp. 1703-1710.
- [13] Bañón AM, Josefa HR. Growth conditions influence the melatonin content of tomato plants. *Food Chemistry.* 2013, 138 (2-3): pp. 1212-1214.
- [14] Dominguez I, Lafuente MT, Hernandez-Muioz P, Gavara R. Influence of modified atmosphere and ethylene levels on quality attributes of fresh tomatoes (*Lycopersicon esculentum* Mill.). *Food Chemistry.* 2016, 209: pp. 211-219.
- [15] AOAC. Analytic Official Methods of Analysis of the Association Chemists., 1990.
- [16] AFNOR. Association Française de Normalisation. Recueil des normes françaises des céréales et des produits céréaliers. Troisième édition: 1991, pp. 1-422
- [17] FAO. Food energy - methods of analysis and conversion factors. *Food And Nutrition.* 2002, Paper 77: pp. 93p.
- [18] Pelletier F, St-Louis D. Etude cinétique à l'ombre et à la lumière de la vitamine C, *Sciences de la nature.* 1999.
- [19] Benakmoum A, Abbeddou S, Ammouche A. Valorisation of low quality edible oil with tomato peel waste. *Food Chemistry.* 2008, 110: pp. 684-690.
- [20] Singleton VL, Orthofer R, Lamuela-Raventos RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of the Folin-Ciocalteu reagent. *Methods Enzymology.* 1999, 299: pp. 152-178,.
- [21] Wood Senthilmohan ST. antioxidant activity of procyanidin-containing plant extracts at different pHs. *Food Chemistry.* 2002, T.77: pp. p.155-164.
- [22] Marinova RF, Atanassova M. Total phenolics in bulgarian Fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy.* 2005, T.40, N°3: pp. p.255-260.
- [23] Von Gadow A, Joubert E, Hansmann CF. Comparison of antioxidant activity of aspalathin with that of other plant phenols of rooibos tea (*Aspalathus linearis*), alpha-tocopherol, BHT and BHA. *Journal of Agricultural and Food Chemistry.* 1997, 45: pp. 632-638.

- [24] Molyneux P. The use of stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin J. Sci. Technol.* 2004, 26 (2): pp. 211-219.
- [25] Maria M. Gil Fátima A, Miller, Teresa RS, Brandão C, Silva LM. Combined effects of temperature, pH and water activity on predictive ability of microbial kinetic inactivation model, 9th International Conference on Predictive Modelling in Food *Procedia Food Science.* 2016, 7: pp. 67 - 70,.
- [26] Ji-Yeon Lee, Sang-Soon Kim, Dong-Hyun Kang. Effect of pH for inactivation of *Escherichia coli* O157:H7, *Salmonella Typhimurium* and *Listeria monocytogenes* in orange juice by ohmic heating. *Lwt. Food Science And Technology.* 2015, 62: pp. 83-88.
- [27] Guil-Guerrero JL, Reboloso-Fuentes MM. Composition and Analysis Nutrient composition and antioxidant activity of eight tomato (*Lycopersicon esculentum*) varieties. *Journal of Food Composition and Analysis journal.* 2009, 22: pp. 123-129.
- [28] Pinela JL, Barros AM, Carvalho IC, Ferreira FR. Nutritional composition and antioxidant activity of four tomato (*Lycopersicon esculentum L.*) farmer' varieties in Northeastern Portugal homegardens. *Food and Chemical Toxicology.* 2012, 50(3-4): pp. 829-834.
- [29] Halevy S, Koth H, Guggenheim K. The vitamin and mineral content of fruits and vegetables grown in Israel. *British Journal of Nutrition.* 2007, 11(04): pp. 409.
- [30] Prasad AS. An Antioxidant And Anti-Inflammatory Agent: Role Of Zinc In Degenerative Disorders Of Aging. *ournal of Trace Elements in Medicine and Biology,* 2014.
- [31] Silvestro RD. Zinc in relation to diabetes and oxidative disease. *J Nutr.* 2000, 130: pp. 1509S-1511S.
- [32] Houston M. The importance of potassium in managing hypertension. *Curr. Hypertens. Rep.* 2011, 13(4): pp. 309-317.
- [33] Whelton P, He J. Potassium in preventing and treating high blood pressure. *Semin. Nephrol.* 1999, 19: pp. 494-499.
- [34] Flood A, Peters U, Chatterjee N, Lacey JJ, Schairer C, Schatzkin A. Calcium from Diet and supplements is associated with reduced risk of colorectal cancer in a prospective cohort of women. *Cancer Epidemiology Biomarkers & Prevention.* 2005, 14(1): : pp. 126-132.
- [35] Fournier P, Dupuis Y., *Métabolisme minéral des mammifères. Eléments de Nutrition Dynamique. Edition personnelle Volume VIII, 2009.*
- [36] Laurant P, Touyz RM. Physiological and pathophysiological role of magnesium in the cardiovascular system: Implication in hypertensive. . *J. Hypertens.* 2000, 18.1177-1191.
- [37] Widman L, Wester PO, Stegmayr BG, Wirell MP. The dose dependant reduction in blood pressure through administration of magnesium: A double blind placebo controlled cross-over trial. . *Am. J. Hypertens.* 1993, 6, 41-45.
- [38] Raffo A, Leonardi C, Fogliano V, Ambrosino P, Salucci ML, Gennaro R, Bugianesi, F. Giuffrida, Quaglia G. Nutritional value of cherry tomatoes (*Lycopersicon esculentum cv. Naomi FI*) harvested at different ripening stages. *Journal of Agricultural and Food Chemistry.* 2002, 50(22): pp. 22.
- [39] Carr A, Frei B, Does vitamin C act as a pro-oxidant under physiological conditions. *The FASEB Journal.* 1999, 13: pp. 1007-24.
- [40] Kelly F. L'utilisation des antioxydants dans la prévention et le traitement de la maladie. *Journal de la Fédération internationale de chimie clinique.* 1998, IFCC 10 (1):: pp. 21-3 PMID 10181011.

- [41] Mayne S. Nutrimentes antioxydants et les maladies chroniques : l'utilisation de biomarqueurs d'exposition et état de stress oxydatif dans la recherche épidémiologique. *Le Journal de la nutrition*. 2003, 133 Suppl 3: 940S. 933S PMID 12612179.
- [42] Burns J, Paul D, Fraser P, Bramley M. Identification and quantification of carotenoids, tocopherols and chlorophylls in commonly consumed fruits and vegetables. *Phytochemistry*. 2003, 62: pp. 939-947.
- [43] Khachik F, Carvalho L, Bernstein PS, Garth J, Muir DZ, Katz NB. Chemistry, distribution, and metabolism of tomato carotenoids and their impact on human health. *Experimental Biology and Medicine*. 2002, 227: pp. 845-851.
- [44] Schierle Bretzel W, Buhler I, Faccin N, Hess D, Steiner K. Contents and isomeric ratio of lycopene in food and human plasma. *Food Chemistry*. 1996, 59: pp. 459-465.
- [45] Gross J. *Pigments in fruits*. London: Academic Press, 1987.
- [46] Abushita AA, Daood HG, Biacs PA. Change in Carotenoids and Antioxidant Vitamins in Tomato as a Function of Varietal and Technological Factors. *Journal of Agricultural and Food Chemistry*. 2000, 48: pp. 2075-2081.
- [47] Binoy G, Kaur C, Khurdiya DS, Kapoor HC. Antioxidants in tomato (*Lycopersium esculentum*) as a function of genotype. *Food Chemistry*. 2004, 84: pp. 45-51.
- [48] Leonardi C, Ambrosino P, Esposito F, Fogliano V. Antioxidative Activity and Carotenoid and Tomatine Contents in Different Typologies of Fresh Consumption Tomatoes. *Journal of Agricultural and Food Chemistry*. 2000, 48: pp. 4723-4727.
- [49] Strazzullo G, De Giulio A, Tommonaro G, La Pastina C, Poli A, Nicolaus B, De Prisco R, Saturnino C. Antioxidative activity and lycopene and beta-carotene contents in different cultivars of tomato (*Lycopersicon esculentum*). *International Journal of Food Properties*. 2007, 10: pp. 1-9.
- [50] Hinneburg I, Neubert RH. Influence of extraction parameters on the phytochemical characteristics of extracts from buckwheat (*Fago- pyrum esculentum*) herb. *Journal of Agriculture and Food Chemistry*. 2005, 53: pp. 3-7.
- [51] Mukhopadhyay S, Luthria, DL, Robbins RJ. *Optimization of extraction process for phenolic acids from black cohosh (Cimicifuga racemosa) by pressurized liquid extraction*. *Journal of the Science of Food and Agriculture*. 2006, 86: pp. 156-162.
- [52] Borguini R, Torres E, Tomatoes and tomato products as dietary sources of antioxidants. *Food Reviews International*. 2009, 25: pp. 313-325.
- [53] Frusciante L, Carli P, Ercolano MR, Pernice R, Di Matteo A, Fogliano V, Pellegrini N. *Antioxidant nutritional quality of tomato*. *Molecular Nutrition & Food Research*. 2007, 51: pp. 609-617.
- [54] Balasundram N, Sundram K. Phenolic compounds in plants and agri-industrial by-products: antioxidant activity, occurrence, and potential uses. *Food Chem. Toxicol*. 2006, 99: 191-203.
- [55] Dai J, Mumper RJ. Plant phenolics: extraction, analysis and their antioxidant and anticancer properties, *Molecules*. 2010, 15(10): 7313-7352.
- [56] Obrenovich ME, Nair NG, Beyaz A. *The Role of Polyphenolic Antioxidants in Health, Disease, and Aging*. *Rejuvenation Research*. 2010, 13(6): 1-13.

Table 1: Physicochemical parameter of four tomato varieties per 100 g of fresh tomato

<i>Local cerise</i>	3.60 ± 0.05 ^a	93.99 ± 0.34 ^b	6.01 ± 0.34 ^b	26.00 ± 2.00 ^c	0.71 ± 0.08 ^{b,c}
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These values are mean value \pm standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.

Table 2: Macronutrient composition of four varieties of tomato per 100 g of fresh tomato

	Carbohydrates (g)	Lipids (g)	Proteins (g)	Energy value (Kcal)	Fibers (g)	<i>These values are mean values \pm standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.</i>
UC82b	4.40 \pm 0.02 ^b	0.05 \pm 0.01 ^a	0.74 \pm 0.06 ^a	21.02 \pm 0.43 ^a	1.02 \pm 0.11 ^{a,b}	
<i>Amiral FI</i>	3.48 \pm 0.02 ^a	0.11 \pm 0.01 ^{a,b}	0.76 \pm 0.01 ^a	17.99 \pm 0.09 ^a	0.701 \pm 0.03 ^a	
<i>Local cotelette</i>	5.58 \pm 0.14 ^c	0.43 \pm 0.23 ^{b,c}	1.46 \pm 0.06 ^c	32.03 \pm 1.50 ^c	2.04 \pm 0.38 ^c	
<i>Local cerise</i>	3.56 \pm 0.08 ^a	0.79 \pm 0.14 ^c	0.95 \pm 0.05 ^b	25.15 \pm 1.73 ^b	1.48 \pm 0.04 ^b	

These values are mean value \pm standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.

Table 3: Mineral compositions of four varieties of tomato in mg per 100 g of fresh tomato

	<i>UC82b</i>	<i>Amiral FI</i>	<i>Local cotelette</i>	<i>Local cerise</i>
Ca	20.65 \pm 0.52 ^a	19.88 \pm 0.07 ^a	30.99 \pm 0.30 ^b	22.23 \pm 2.38 ^a
Fe	0.065 \pm 0.02 ^a	0.046 \pm 0.13 ^a	0.05 \pm 0.02 ^a	0.05 \pm 0.03 ^a
Mg	15.89 \pm 0.57 ^b	11.85 \pm 0.04 ^a	20.99 \pm 0.20 ^c	17.02 \pm 1.82 ^b
P	22.62 \pm 0.82 ^c	12.90 \pm 0.05 ^a	16.41 \pm 0.14 ^b	19.68 \pm 2.10 ^c
K	313.47 \pm 11.40 ^b	248.39 \pm 1,14 ^a	332.67 \pm 3.12 ^b	313.04 \pm 32.79 ^b
Mn	0.09 \pm 0.03 ^a	0.06 \pm 0,03 ^a	0.06 \pm 0.01 ^a	0.07 \pm 0.02 ^a
Zn	0.11 \pm 0.03 ^b	0.06 \pm 0.01 ^a	0.08 \pm 0.01 ^{a,b}	0.07 \pm 0.00 ^{a,b}

These values are mean value \pm standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.

Table 4: Antioxidant compounds content of four varieties of tomato per 100 g of fresh tomato

	Vitamin C (mg)	Carotenoids (mg eq β -carotene)	Lycopenes (mg)	Polyphenols (mg EAG)	Flavonoids (mg EQ)
UC82b	20.34 \pm 0.00 ^b	21.60 \pm 1.00 ^c	2.04 \pm 0.30 ^b	16.50 \pm 1.30 ^b	1.98 \pm 0.50 ^a
<i>Amiral FI</i>	9.04 \pm 0.00 ^a	13.00 \pm 0.30 ^a	1.77 \pm 0.03 ^a	17.49 \pm 3.70 ^c	2.60 \pm 0.00 ^b
<i>Local cotelette</i>	35.40 \pm 6.52 ^c	15.90 \pm 0.10 ^b	2.95 \pm 0.14 ^c	16.20 \pm 2.00 ^b	2.50 \pm 1.50 ^b
<i>Local cerise</i>	31.64 \pm 0.00 ^c	17.00 \pm 0.30 ^b	2.15 \pm 1.20 ^b	12.80 \pm 1.50 ^a	3.10 \pm 1.00 ^c

These values are mean value \pm standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.

Table 5: Antioxidant activity of four varieties of tomato

		EC ₅₀ (mg/mL)
	UC82b	6.27 \pm 0.14 ^d
<i>Variety of tomato</i>	<i>Amiral FI</i>	3.47 \pm 0.16 ^b

	<i>Local cotelette</i>	4.26 ± 0.16 ^c
	<i>Local cerise</i>	6.74 ± 0.27 ^e
Reference	<i>Vitamin C</i>	2.72 ± 0.06 ^a

These values are mean value ± standard error of means of 3 experiments. Values with the same letters in the same column are not significantly different at $p < 0.05$.