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Effect of Heat Treatment on Antioxidant Capacity and Antioxidant Compounds of Eight Tomato Varieties from Four Growing Areas in Côte d'Ivoire

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Abstract: The tomato (*Lycopersicon esculentum* mill) is a fruit with high antioxidant power. It contains the secondary metabolites carotenoids (lycopene) and phenolic compounds. Tomatoes are also an excellent source of vitamins such as vitamin C, E and several B-group vitamins, as well as minerals (potassium, magnesium, calcium, phosphorus, iron, manganese, zinc). However, heat treatment can influence to a greater or lesser extent the presence of these antioxidant compounds and the antioxidant activity in different tomato varieties. The aim of this study is to assess the influence of heat treatment on antioxidant activity and antioxidant compounds in eight tomato varieties from four major growing areas in Côte d'Ivoire. The fresh tomatoes collected and the tomato powders obtained underwent heat treatment at different times (10 min, 20 min and 30 min), after which the supernatant or grindings were used for the determination of phenolic compounds, lycopene, vitamin C and antioxidant activity by DPPH. The results showed that heat treatment reduced phenolic and vitamin C content in all the tomato varieties studied, compared with the respective fresh tomatoes. On the other hand, the lycopene content and antioxidant activity of heat-treated tomato varieties increased in comparison with those of the respective fresh tomatoes. These results could justify the recommendation of tomato sauces by dieticians in the prevention of oxidative stress and, by extension, metabolic diseases.

Keywords: Antioxidant Activity, Lycopene, Phenolic Compounds, Tomato, Heat Treatment

1. Introduction

The tomato (*Lycopersicon esculentum* Mill.) is a fruiting vegetable native to the fertile valleys of Mexico, consumed in various forms (fresh or processed). Its consumption boomed from the 19th century onwards, fuelled by cross-border trade. Today, in terms of production volume, it is the 2nd most important vegetable crop in the world, with 34 million tonnes per year, after potatoes [1]. It is a real source of micronutrients (vitamins and minerals) and secondary metabolites. Vitamins such as A, B1, E and C are present at varying levels [2, 3]. Tomatoes also contain minerals such as potassium, chlorine, magnesium, phosphorus, trace elements (iron, zinc, copper, cobalt, boron, nickel, iodine) and fiber [4]. All these assets make tomatoes a food particularly recommended by dieticians [5].

The value of tomato consumption also lies in the fact that this fruit contains numerous secondary metabolites and other compounds with antioxidant power, notably flavonoids such as rutin and hydroxycinnamic acid derivatives [6]. This fruit also contains carotenoids such as lycopene and beta-carotene, which in addition to being responsible for the tomato's red and yellow color respectively, are well known for their strong antioxidant power [7].

Since the 90s, consumers have been complaining about product standardization and loss of taste [8]. Current research is increasingly focused on characterizing and improving the organoleptic quality of this fruit. This loss of physico-chemical and organoleptic characteristics is thought to be due to a number of factors, notably processing, which can have an impact on the availability of certain antioxidant nutrients or compounds in tomatoes, such as vitamin C, lycopene and phenolic compounds. The aim of this study is to evaluate the effect of different heat treatment times on the antioxidant capacity and antioxidant compounds, in particular lycopene, vitamin C and total polyphenol contents of eight tomato varieties grown in Côte d'Ivoire.

2. Materials and Methods

2.1. Materials

The study material consisted of 8 tomato varieties, including 4 hybrids (*Cobra F1*, *Kiara F1*, *Amiral F1* and *Emirald F1*) and 4 traditional varieties (*Locale cerise*, *Locale côtelette*, *Petometch* and *UC82b*). These varieties were collected in 4 major growing areas in Côte d'Ivoire: Yamoussoukro, Bouaké, Daloa and Abengourou.

2.2. Methods

2.2.1. Sample Preparation

Three different flasks (1, 2 and 3) were filled with 50 g of tomato powder and 500 mL of distilled water. Flasks 1, 2 and 3 were then topped with a condenser and heated under reflux for 10, 20 and 30 min respectively. The broths were then divided into 2 parts. The first part of the broth was dried directly in an oven at 60°C for 48 hours. The second part of the broth was centrifuged at 1000 rpm for 10 min. The supernatant (extract) obtained was oven-dried at 60°C for 48 hours.

2.2.2. Determination of Antioxidant Compounds

(i). Determination of Total Polyphenols and Vitamin C

Phenolic compounds were assayed in tomato extracts according to the method described by Singleton [9] and Wood *et al.* [10], using the Folin-Ciocalteu reagent. Vitamin C was determined by the method described by Pelletier and Daphney [11], using 2,6-dichlorophenol-indophenol (DCPIP).

(ii). Lycopene Assay

Lycopene in dried tomato broth was determined using the method described by Benakmoom *et al.* [12]. Lycopene content was determined according to the following formula:

$$Lycopene\ content\ (\mathrm{mg/100g}) = \frac{(\mathrm{Abs}_{472} \times \mathrm{Fd} \times 10^6 \times \mathrm{V})}{3450 \times 100 \times \mathrm{m}}$$

Df: Dilution factor
V: Volume of extraction solvent
3450: Hexane extinction coefficient
m: Weight of test sample

(iii). Determining the Antioxidant Activity of Tomatoes Using the DPPH Radical

Antioxidant activity using DPPH was determined according to the method described by Von Gadow [13]. This involved determining the percentage of DPPH inhibition by tomato extracts and their 50% effective concentration (EC50).

2.2.3. Statistical Analysis

Statistical analysis was carried out using a one-factor analysis of variance (1-factor ANOVA) for all data (mean of each dosed parameter). This analysis was performed using GraphPad Prism 7 software. Comparisons of means were made using the Newman-Keuls test at the 5% significance level.

3. Results

Figure 1 shows the effect of heat treatment on the vitamin C content of 8 tomato varieties grown in Côte d'Ivoire. Heat treatment led to a reduction in vitamin C levels in the various tomato samples studied. Depending on the variety studied, this reduction could reach 90% after 10 min of heat treatment. After 20 and 30 min of heat treatment, the vitamin C content of the various tomato samples was zero.

Figure 2 shows histograms highlighting the effect of heat treatments on phenolic compounds in 8 tomato varieties from 4 major growing areas in Côte d'Ivoire. These results show that, for all tomatoes studied, polyphenol levels decrease with the duration of heat treatment. Indeed, after 30 min of heat treatment, the percentage reduction in polyphenols in the tomatoes studied ranged from 16.46% to 77.16% compared with the initial value. The *Cobra F1* variety from Abengourou (ACOB) showed the highest percentage reduction, while the *Locale cerise* variety from the same locality (ALCE) had the lowest. With the exception of YCOB, all hybrid varieties have a reduction percentage of over 40%. Improved tomato varieties are more sensitive to heat treatment than traditional varieties.

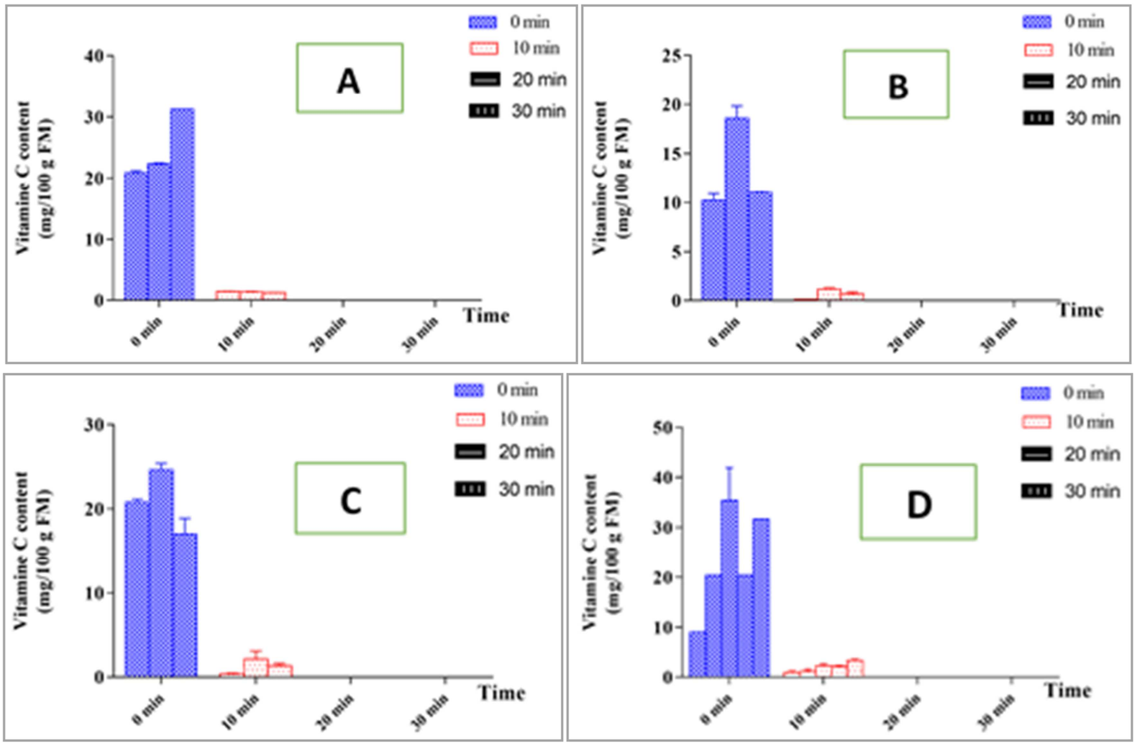


Figure 1. *Effect of heat treatment on vitamin C content of tomato samples.*

A= varieties from Abengourou, B= varieties from Bouaké, C= variety from Daloa, D= variety from Yamoussoukro. These histograms represent the average of 3 trials.

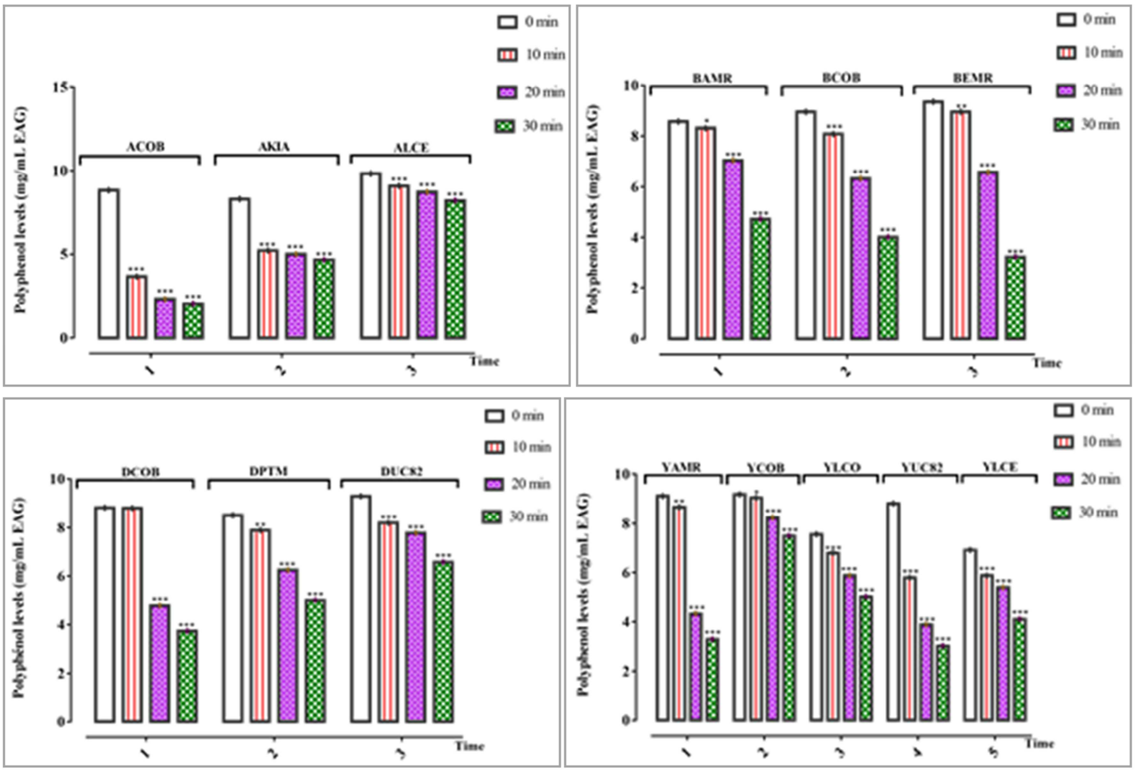
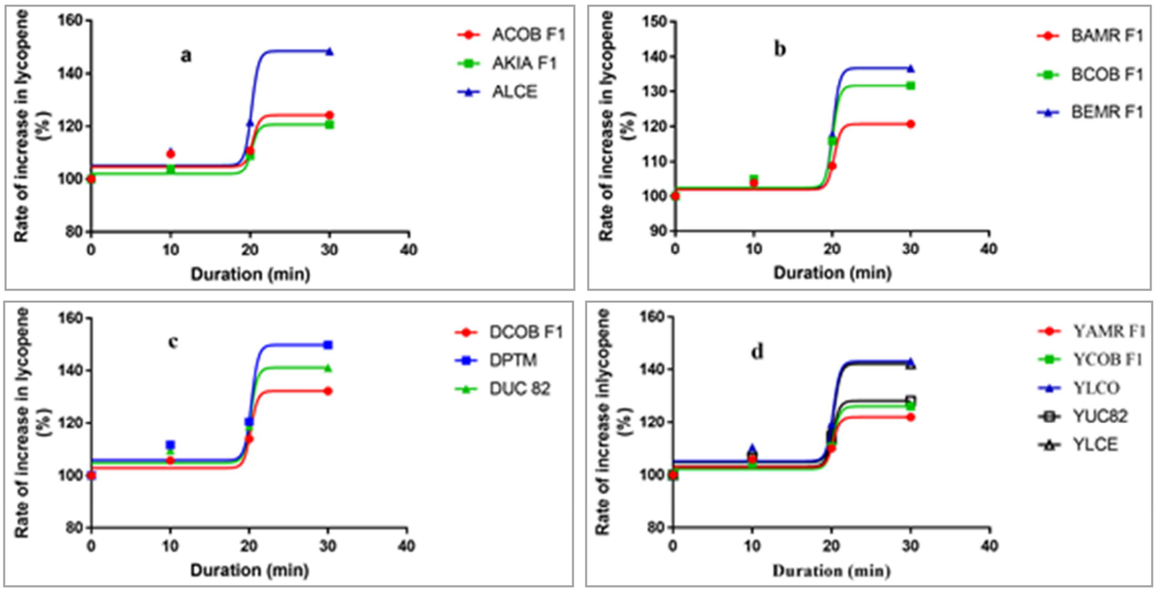


Figure 2. *Effect of heat treatment on phenolic compounds in tomato samples.*

ACOB, AKIA, ALCE=(Abengourou varieties); BAMR, BCOB, BEMR=(Bouaké varieties); DCOB, DPTM, DUC82= (Daloa varieties); YAMR, YCOB, YLCO, YUC82, YLCE=(Yamoussoukro varieties). These histograms represent the average of 3 trials. ***p<0.001: highly significant difference compared to polyphenol level at 0 min.**p<0.01: moderately significant difference compared to polyphenol level at 0 min.*p<0.05: weakly significant difference compared with polyphenol level at 0 min.

Figure 3 shows the effect of heat treatment on lycopene levels in 8 tomato varieties grown in Côte d'Ivoire. Heat treatment resulted in an increase in the lycopene content of the tomatoes studied. The percentage increase ranged from 120.71% to 148.50% after 30 min of heat treatment. This increase is remarkable around 20 min of heat treatment and depends on the variety studied. *Locale cerise* from Abengourou *(ALCE)* showed the highest percentage increase at 148.50%, while *BAMR F1* showed the lowest at 120.71%. However, the rate of lycopene increase in traditional varieties is higher than in hybrid varieties following heat treatment.



a= varieties from Abengourou, b= varieties from Bouaké, c= varieties from Daloa, d= varieties from Yamoussoukro.

Figure 3. *Effect of heat treatment on lycopene in tomato samples.*

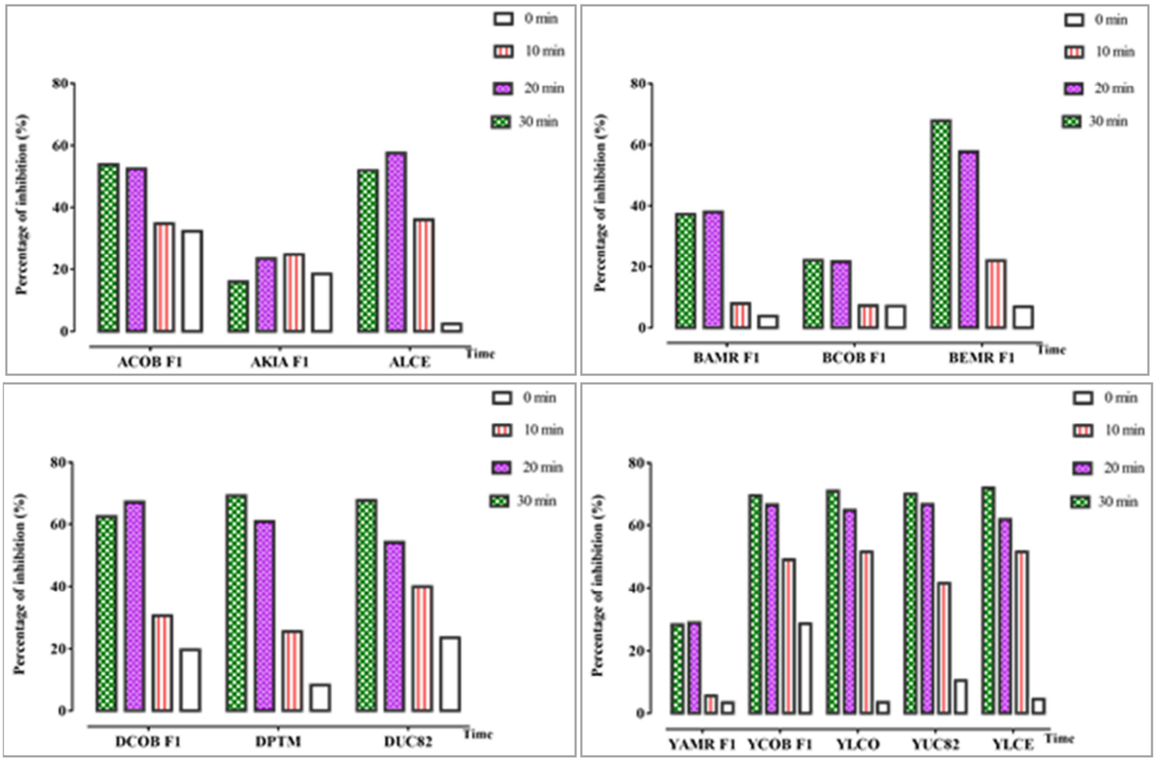


Figure 4. *Effect of heat treatment on antioxidant activity of tomato samples.*

ACOB, AKIA, ALCE = (Abengourou's varieties); BAMR, BCOB, BEMR = (Bouaké's varieties); DCOB, DPTM, DUC82= (Daloa's varieties); YAMR:, YCOB:, YLCO, YUC82:, YLCE = (Yamoussoukro's varieties).

Figure 4 shows the antioxidant activity of the 8 tomato varieties following heat treatment. This activity was demonstrated by determining the percentage of DPPH radical inhibition in the various tomato water extracts. The percentage inhibition of the tomato extracts studied ranged from 15% to 71.07% after 30 min of heat treatment. The lowest inhibition percentage was obtained with the *Kiara F1* variety from Abengourou (15.93%), while the *Locale côtelette* variety from Yamoussoukro (YLCO) showed the highest inhibition percentage (71.07%).

Varieties from the Yamoussoukro locality, notably YLCE and YLCO, showed the highest inhibition percentages, with 72.05% and 71.07% respectively at 30 min of treatment.

4. Discussion

The antioxidant compounds in tomatoes comprise two fractions: the hydrophilic fraction comprising vitamin C and phenolic compounds, and the lipophilic fraction composed mainly of vitamin E and carotenoids, with lycopene as the major carotenoid [6, 14]. The presence of these compounds with high antioxidant power in tomatoes would prevent several metabolic diseases [6, 15]. However, tomatoes can be eaten both fresh and processed. Cooking tomatoes can lead to variations in the content of these compounds.

Heat treatment at different times applied to different tomato varieties has shown that heat leads to a decrease in polyphenol and vitamin C content whatever the tomato variety. On the other hand, heat treatment increased lycopene levels and antioxidant activity in tomatoes, reaching a 72% inhibition rate. According to Lenucci et al [16], the hydrophilic fraction is more sensitive to heat than the lipophilic fraction, so heat treatment would have led to the denaturation of part of the hydrophilic fraction. The high antioxidant activity of heat-treated tomato varieties could be linked to the lipophilic fraction, notably lycopene. Lycopene, present in the tomato cell matrix, is released when the cell is destroyed during heat treatment [17]. This would explain the increase in lycopene in cooked tomatoes. What's more, as lycopene is present in fresh tomatoes in the trans configuration, heat treatment favors the accessibility of these trans-lycopenes. These trans-lycopenes will bind energy from other unstable molecules and transform into cis-lycopenes [18]. Increasing this energy will therefore lead to strong isomerization, with lycopene gradually shifting from the trans to the more thermostable cis configuration [18]. This would increase the concentration of lycopene in tomato broths, thus boosting the antioxidant capacity of tomato samples.

5. Conclusion

This study has demonstrated the effect of heat treatment on the antioxidant capacity and antioxidant compounds present in the eight tomato varieties grown in Côte d'Ivoire. Heat treatment reduced phenolic and vitamin C content in all tomato varieties studied, compared with fresh tomatoes. On the other hand, the lycopene content and antioxidant activity of heat-treated tomato varieties increased in comparison with those of the respective fresh tomatoes. This high antioxidant capacity was more pronounced with traditional varieties than with improved varieties.

Regular consumption of tomato sauces could therefore be beneficial in preventing oxidative stress and, by extension, metabolic diseases. However, further studies on the phytochemical screening of tomato varieties grown in Côte d'Ivoire are still needed.

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