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Research Article

VARIATION OF THE BIOCHEMICAL PARAMETERS OF TWO VARIETIES OF COOKED OKRA (ABELMOSCHUSCAILLEI AND ABELMOSCHUSESCULENTUS) ACCORDING TO THE STAGES OF MATURITY

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A B S T R A C T

The present work aims to study the variation of the biochemical parameters between two water-cooked varieties of okra (*Abelmoschuscaillei and Abelmoschusesculentus*), to determine the stage of maturity with the best nutritional profile after cooking. The plant material was harvested at 4 different stages of maturity: 5, 10, 15 and 20 days after flowering. Some phenolic compounds, biochemical parameters and minerals have been determined. The results showed a significant decrease in phenolic compounds and minerals (Fe, Ca, P, K) until the 20th day of maturity for the both varieties of okra. However, there is also a significant decrease in most biochemical parameters up to the 20th day of maturity, excepted the soluble fibres and lipids. At 15 days of maturity, the Koto variety provided the highest levels of flavonoids (12.77 mg/100 g DM) and antioxidant activity (953.18 mg/100 g DM). On the other hand, the Tomi variety showed the highest value of polyphenols (119. 59 mg / 100g MS) and oxalate (362. 01 mg/100g MS). At 15 days of maturity, the Koto variety recorded the highest levels of phosphorus (11.44 mg/100g MS) and potassium (247.89 mg/100g MS) while the Tomi variety obtained high values in iron (1.07 mg/100 g MS) and calcium (214 mg/100 g MS). Thus, cooked okra, because of its high content in soluble fibers and its low content in fat, could be recommended for a weight loss, lipid-lowering and hypoglycaemic diets.

INTRODUCTION

For most developing countries, market gardening is a major component of the agricultural economy. It is one of the pillars of food security and the main source of income for people in rural areas. In Côte d'Ivoire, market gardening of okra is much more developed in pre-forest and forest areas (Akassey and Daubrey, 1992). Thus, are identified in Côte d'Ivoire, AbelmoschusesculentusKoto and AbelmoschuscailleiTomi varieties (Siemonsma, 1982). They are resistant to heavy rains and can produce fruit even during the dry season (Siemonsasma, 1982, Shippers, 2002). Côte d'Ivoire is the second largest African producer of okra after Nigeria and is ranked 4th in the world with 105,597 tons (Fondio *et al.* 2007). Vegetable fruits are generally harvested at the juvenile stage of their maturity and are mainly used in sauce. These sauces are prepared either with fresh fruit or with dried fruit cut into slices or not and transformed into powder (Grubben *et al.* 2004). Indeed, okra is the second most consumed vegetable after tomatoes (Hamon and Charrier, 1997).

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It undergoes several heat treatments before its consumption. These treatments could influence the bioavailability of micronutrients and cause the loss of minerals or the destruction of vitamins at high temperatures (Hélène Pineau, 2004). In Ivory Coast, okra is a vegetable that is eaten fresh after cooking. It can undergo various technological treatments among which, water-cooking is the most used. This cooking mode causes the loss of many biochemical compounds compared to the fresh state. Indeed, cooking leads to a loss of certain nutrients, either by the diffusion of water-soluble constituents in the cooking water, or by the destruction of thermolabile substances (RoccaPoliméni, 2007). The purpose of this work is to study the variation of biochemical parameters of okra cooked at different stages of maturity to determine the stage of maturity with the best nutrient profile after cooking.

MATERIAL AND METHODS

Experimental site, plant material and cropping practice

The two varieties of Okra (Abelmoschusesculentus (Koto) and Abelmoschuscaillei (Tomi)), used for this research work, have been brought from Malbaie, Abobo (Abidjan-Côte d'Ivoire). The experimental device used was done according to the model of Fisher with three repetitions in two blocks covering a

surface of 11.25 m2 (1.50 m×7.50 m).

The experimental device has been sown on a plot of 1.5 m x 7.5 m. A plot of 1.5m x 7.5 m composed of twenty-two holes constitutes. The holes of the plot were separated by 0.5 m x 1 m. Before sowing, the ground was ploughed manually then enriched with 250 kg/ha by manure NPK 10-18-18. After the appearance of the first leaves of about five centimetres, guardians were assigned to each plant. Seedlings were rejected after the emergence of way to keep only the strongest plant. Okra was harvested at four stages of maturity which are respectively 5, 10, 15 and 20 days after flowering for each variety.

Collection and sampling

The cooking of okra fruits was done according to Randrianatoandro's method (2010). Five hundred grams (500 g) of fresh fruits were immersed in 1.5 L of demineralized water and boiled at 100 ° C for 45 min. The fruits were cooked at this temperature until they were soft and the colouring of the seeds turned from white to purple. After cooking, the okra fruits were drained and cooled to room temperature. The cooked okra's water was evaporated in an oven (45 ° C, 24 h) and then the dried water-cooked fruits were reduced to okra flour.

Proximate Composition Analysis

Dry matters were determined by drying in an oven at 105ºC during 24 h to constant weight (AOAC, 1990). Method described by Dubois *et al*. (1956) was used to determine total sugars while reducing sugars were analysed according to the method of Bernfeld (1955) using 3.5 dinitrosalycilic acids (DNS). Crude protein was calculated from nitrogen (N x 6.25) obtained using the Kjeldahl method by AOAC (2005). Crude fat was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent (AFNOR, 1973) according to standard NF V03-905. Vitamin C was determined according to the method of Tomohiro (1990). The crude fibre contents were determined according to the method of Van Soest (1963). Total carbohydrates were calculated by difference. Total ash was determined by incinerating in a furnace at 550ºC (AOAC, 1990).

Minerals analysis

Minerals were determined employing AOAC (1990) method. Powder was digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analysed using an atomic absorption spectrophotometer. The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (APHA, 1995).

Phytochemical composition

Extraction of phenolic compounds

Extraction of phenolic compounds were determined employing Singleton *et al*. (1999) method. A sample (10 g) of okra powder was extracted by stirring with 50 ml of methanol 80 % (v/v) at 25°C for 24 hours and filtered through Whatman no 4 paper. The residue was then extracted with two additional 50 ml portions of methanol. The combined methanolic extracts were evaporated at 35°C (rotary evaporator HEILDOLPH Laborata 4003 Control, Schwabach, Germany) until 25 ml, prior to phenolic compound contents determination.

Determination of total phenolic compounds content

Contents of total phenolic compounds were estimated according Folin-Ciocalteu method (Singleton *et al*., 1999). A volume of 1 ml of methanolic extract of each sample was added to 1 ml of Folin-Ciocalteu's solution in a test tube. After 3 minutes, 1 ml of 20 % sodium carbonate solution was added to the mixture and adjusted to 10 ml with distilled water. The mixture could stand at room temperature in a dark environment for 30 min. Absorbance was measured against the blank reagent at 725 nm. Gallic acid was used for the calibration curve with a concentration range of 50-1000 µg/ml. Results were expressed as mg gallic acid equivalent (GAE)/100g DW (Dry Weight).

Determination of flavonoids

Total flavonoids content was determined according method used by Meda *et al*. (2005), but slightly modified. A volume of 0.5 ml of methanolic extract of sample was diluted in 0.5 ml of distilled water. Then, 0.5 ml of aluminium chloride 10 % (P/V) and the same volume of sodium acetate 1M were added. Finally, 2 ml of distilled water was added and absorption reading at 415 nm was carried out after 30 min against a blank sample consisting of a 4 ml methanolic extract without aluminium chloride. Quercetin was used for the calibration curve with a concentration range of 0-100 µg/ml. Results were expressed as mg of quercetin equivalent (QE)/100g DW.

Determination of oxalates

Oxalates content was determined using the method described by Day and Underwood (1986). A sample (2 g) of dried okra powders was homogenized in 75 ml of H_2SO_4 (3M). The mixture obtained was put under magnetic agitation during 1 H at the ambient temperature (28 C). The whole was filtered on filter paper Whatman n4. Twenty-five (25) ml of filtrate were titrated hot by a permanganate solution of potassium (KMnO4) to 0.05 M until the turn with the pink persisting. The content oxalates were obtained by the equation:

Veq: volume (ml) of KMnO4 poured with equivalence
me: sample mass (g). $\text{Oxalates (mg/100g)} = \frac{2{,}2\times V_{eq}\times 100}{m_e}$

Estimation of antioxidant activity by DPPH radical scavenging

The DPPH scavenging activity was determined using the method described by Shimada *et al*.(1992). Each sample of methanolic extract (2.5 ml) was mixed with 1 ml of a 3 mM DPPH methanol solution. After 30 min incubation at room temperature in the dark, the absorbance of the mixture was determined at 517 nm against a blank containing methanol without DPPH radical. A lower absorbance indicates a higher scavenging activity. Absorbance was converted to the DPPH radical-scavenging rate according to the equation:
DPPH radical scavenging rate (%) = [(Acontrol-Asample)/Acontrol] x100.

Statistical analysis

The analysis of variance (ANOVA) was used to determine the differences between treatments. When a difference was observed, the multiple range test of Newman-Keuls at 5% was

RESULTS

Phenolic compounds

Statistical analysis showed a significant difference for all levels of phenolic compounds in the two varieties of cooked okra (Figs 1, 2, 3 and 4). For the 2 varieties of cooked okra; there is a significant decrease in the contents of the 5th day until the 20th day of maturity. Also, at each stage of maturity and for both varieties, the levels obtained for the samples of cooked okra are lower than those for the fresh okra.

Thus, the total polyphenol contents of the Koto variety (fresh and cooked) decreased respectively from 76.08 to 70.018 mg/100g DM for the 5thday and from 109.76 to 100.78 mg/100g DM for the 20th day. For the Tomi variety (fresh and cooked), these levels ranged from 74.66 to 68 mg/100g DM for 5thday and 81.08 to 77.6 mg/100 mg DM for the 20th day. With regard to flavonoids, the contents of the Koto variety (fresh and cooked) decreased from 9.46 to 7.25 mg/100g DM for day 5, and from13.01 to 10, respectively). 25 mg/100g MS) for the 20th day. It is also noted that for the Tomi variety (fresh and cooked), the values obtained decreased respectively from 7.23 to 4.5 mg/100g DM for the 5th day, and from 12.6 to 9.5 mg/100g MS for the 20th day. The level of oxalates, at the 5th day of maturity, decreased significantly from 396.65 to 183 and from 382 to 162.05 respectively for Koto and Tomi varieties. On the 20th day of maturity, values decreased from 577.24 to 316.38 and from 606.83 to 362.01 respectively for Koto and Tomi varieties.

The Koto variety recorded an antioxidant activity content which decreased significantly from 653.91 to 640.8 mg/100g DM at day 5 and from 779.5 to 769.55 mg/100g DM at the 20th day of maturity. In the Tomi variety, the levels also decreased from 407.65 to 390 mg/100g DM at the 5th day and from 487.34 to 477.36 mg/100g DM at the 20th day of maturity. At 15 days of maturity, the Koto variety provided the highest levels of flavonoids and antioxidant activity. On the other hand, the polyphenol and oxalate contents were the highest in the Tomi variety

Biochemical Compounds

Statistical analysis showed a significant difference for all levels of biochemical compounds at both fresh and cooked okra varieties (Tables 1, 2 and 3). For the 2 varieties of okra, there is a significant decrease from the 5th day to the 20th day of maturity for most biochemical compounds except soluble fibres and increasing lipids.

Thus, protein levels decreased significantly from 4.79 mg/100g (fresh okra) to 2.6 mg /100g (cooked okra) and from 2.57 mg/100g (fresh okra) to 0.78 mg/100g (cooked okra) on the 5th day of maturity respectively for Koto and Tomi varieties. At 20 days of maturity, the values were 4.67 mg/100g (fresh okra) and 3.01 mg/100g (cooked okra) for the Koto variety and 2.4 mg/100g (fresh okra) and 1.27 mg/100g (cooked okra) for the variety Tomi.

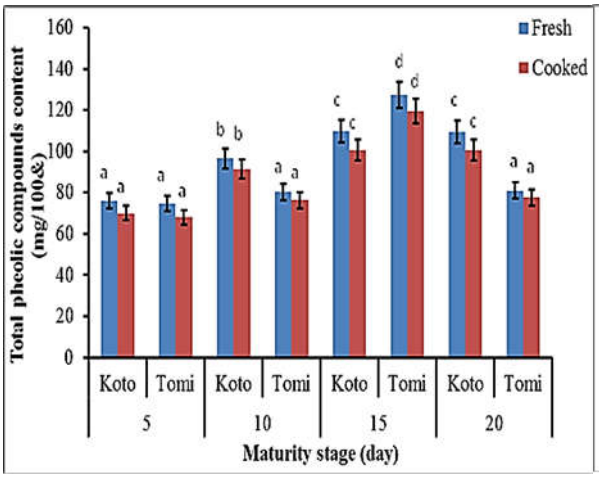

Fig 1 Total polyphenol content of 2 fresh and cooked varieties of okra at different stages of maturity

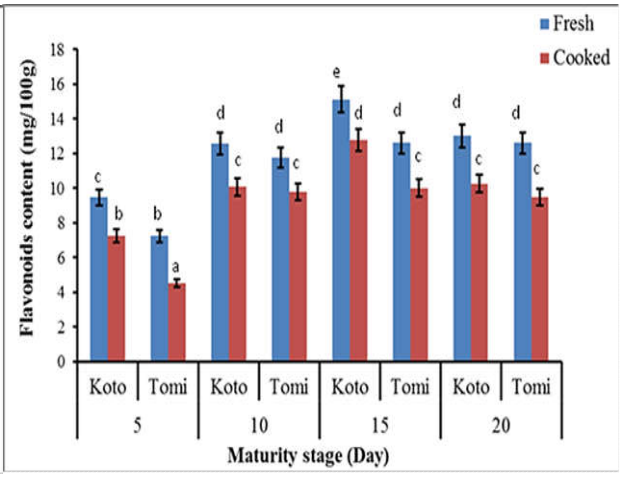

Fig 2 Flavonoid content of 2 fresh and cooked varieties of okra at different stages of maturity

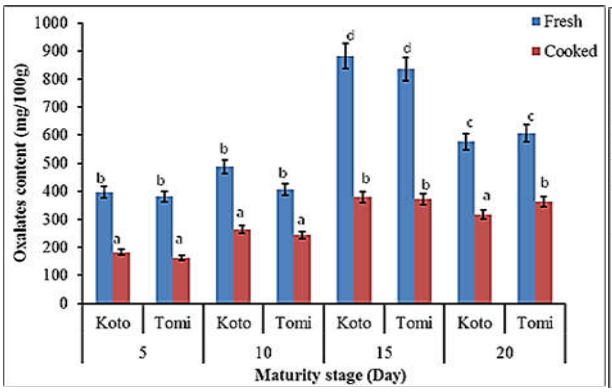

Fig 3 Oxalate content of 2 varieties of fresh and cooked okra at different stages of maturity

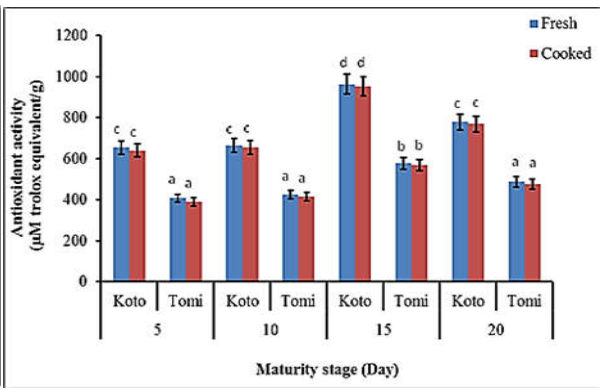

Fig. 4 Antioxidant activity of 2 varieties of fresh and cooked okra at different stages of maturity

Cooked okra had a reducing sugar content which decreased significantly from 0.17 to 0.13 mg/100g at day 5 and from 0.21 to 0.17 mg/100g at day 20 of maturity the Koto variety. At the Tomi variety, this content decreased from 0.12 to 0.10 mg/100g at day 5 and from 0.27 to 0.22 mg/100g at the 20th day of maturity. Similarly, the levels of the Tomi variety decreased with values of 1.04 to 0.80 mg/100g at day 5 and 2.26 to 2.00 mg/100g at day 20 maturity).

The vitamin C contents of the cooked okra samples decreased significantly until the 20th day of maturity at the two varieties of okra. These levels ranged from 4.93 to 0.15 mg/100g DM (5th day of maturity) and 13.59 to 1.02 mg/100g DM (20th day of maturity) and from 2.13 to 0.05 mg/100g MS (5th day of maturity) at 0.15 mg/100g MS (20 days of maturity) respectively for Koto and Tomi. Soluble fibre contents increased with cooking. Thus, for the Koto variety, the soluble fibre contents increased from 15.98 to 16.75 mg / 100g at the (5th day of maturity) and from 31.7 to 36.76 mg/100 g at the 20th day of maturity. While they increased from 9.32 to 10.87 mg/100g (5th day of maturity) and from 17.1 to 23.82 mg/100g (20th day of maturity) for the Tomi variety. About the insoluble fibre content, the Koto and Tomi variety samples recorded respectively 18.57 mg/100g and 11.07 mg/100g (5th day of maturity) and 33.88 mg/100g 19.02 mg/100g (20th day of maturity).

The lipid contents of the 2 cooked okra varieties increased significantly depending on the stage of maturity. Thus, the Koto variety recorded a lipid content which increased to 12.25 mg/100g DM (15t^{h} day of maturity) before falling to 10.54 mg/100g DM (20th day of maturity). In the Tomi variety, this lipid content increased significantly to 8.36 mg/100g DM (15th day of maturity) before falling to 7.12 mg/100g DM (20th day of maturity).

With respect to minerals, iron levels decreased significantly from 0.88 to 0.51 mg/100g DM (5th day of maturity) and from 1. 11 to 0. 71 mg/100g (20th day of days).

Maturity and from 0.93 to 0.67 mg/100g DM (5th day of maturity) and from 1.17 to 0. 98 mg/100g DM (20th day of maturity) respectively for Koto and Tomi varieties. The Tomi variety recorded the highest Iron valuesafter cooking on the 15th day of maturity.

At the phosphorus level, the Koto variety recorded a grade that decreased significantly from 15.21 to 10.47 mg/100g MS at (5th day of maturity) and 15.89 to 10.58 mg/100g MS (20thday of maturity). Into the Tomi variety, the levels decreased after cooking from 12.68 to 8.66 mg/100g DM (5th day of maturity) and 13.37 to 9.86 mg/100g MS (20th day of maturity). At 15thdays of maturity, the variety Koto recorded the highest values in phosphorus.

Table 1 Evolution of some biochemical parameters according to the stagesof maturity of 2 varieties of cooked okra

Biochemical parameters (mg/100g DM)	stage of maturity	Varieties			
		Koto		Tomi	
		fresh	cooked	fresh	cooked
Proteins	5	4,79 ± 0,61^{b}	2,6 ± 0,30^{a}	2,57 ± 0,60^{b}	0,78 ± 0,30^{a}
	10	4,97 ± 0,30^{c}	2,98 ± 0,30^{b}	2,98 ± 0,31^{c}	1,11 ± 0,30^{b}
	15	5,78 ± 0,38^{d}	3,67 ± 0,38^{d}	3, 01 ± 0,30^{d}	1,55 ± 0,6^{d}
	20	4,67 ± 0,51^{a}	3,01 ± 0,61^{c}	2,4 ± 0,60^{a}	1,27 ± 0,31^{c}
Reducing Sugar	5	0,17 ± 0,00^{a}	0,13 ± 0,00^{a}	0,12 ± 0,00^{a}	0,10 ± 0,00^{a}
	10	0,19 ± 0,00^{b}	0,14 ± 0,00^{a}	0,15 ± 0,00^{b}	0,13 ± 0,00^{b}
	15	0,48 ± 0,00^{d}	0,20 ± 0,00^{d}	0,49 ± 0,00^{d}	0,29 ± 0,00^{d}
	20	0,21 ± 0,00^{c}	0,17 ± 0,00^{c}	0,27 ± 0,00^{c}	0,22 ± 0,00^{c}
Total sugar	5	0,99 ± 0,00^{a}	0,47 ± 0,00^{a}	1,04 ± 0,00^{a}	0,80 ± 0,00^{a}
	10	1,19 ± 0,00^{b}	0,76 ± 0,00^{b}	1,20 ± 0,00b	1,10 ± 0,00^{b}
	15	4,21 ± 0,00^{d}	1,06 ± 0,00^{d}	3,64 ± 0,00^{d}	3,13 ± 0,00^{d}
	20	1,35 ± 0,00^{c}	0,99 ± 0,00^{c}	2,26 ± 0,00^{c}	2,00 ± 0,00^{c}
Soluble fibres	5	15,98 ± 0,00^{a}	16,75 ± 0,01^{a}	9,32 ± 0,01^{a}	10,87 ± 0,01^{a}
	10	20,67 ± 0,02^{b}	25,91 ± 0,01^{b}	11,66 ± 0,01^{b}	13,89 ± 0,01^{b}
	15	25,02 ± 0,01^{c}	30,71 ± 0,01^{c}	13,25 ± 0,01^{c}	16,50 ± 0,05^{c}
	20	31,7 ± 0,01^{d}	36,76 ± 0,01^{d}	17,1 ± 0,01^{d}	23,82 ± 0,01^{d}
Insoluble fibres	5	18,72 ± 0,01^{a}	18,57 ± 0,01^{a}	11,77 ± 0,01^{a}	11,07 ± 0,01^{a}
	10	24,32 ± 0,01^{b}	24,00 ± 0,01^{b}	13,66 ± 0,01^{b}	13,11 ± 0,01^{b}
	15	29,32 ± 0,01^{c}	29,02 ± 0,01^{c}	15,47 ± 0,01^{c}	15,06 ± 0,01^{c}
	20	34,02 ± 0,01^{d}	33,88 ± 0,01^{d}	19,16 ± 0,01^{d}	19,02 ± 0,01^{d}
Fat	5	5,04±0,01^{a}	6,77±0,01^{a}	2,71±0,00^{a}	3,82±0,02^{a}
	10	6,13±0,03^{b}	7,70±0,01^{b}	3,7±0,02^{b}	5,20±0,01^{b}
	15	10,26±0,01^{d}	12,25±0,02^{d}	6,78±0,00^{d}	8,36±0,01^{d}
	20	9,18±0,01^{c}	10,54±0,01^{c}	5,88±0,02^{c}	7,12±0,02

Table 2 Evolution of pH and vitamin C according to the stages ofmaturity of 2 varieties of cooked okra

Physicochemicalparameters	stage of maturity	Varieties			
		Koto		Tomi	
		Fresh	Cooked	Fresh	Cooked
pH	5	4,84±0^{a}	4,30±0^{a}	4,98±0,02^{a}	4,60±0^{a}
	10	5,84±0^{b}	4,96±0^{a}	6,15±0^{b}	4,85±0^{b}
	15	6,3±0^{d}	5,04±0^{b}	6,3±0^{d}	5,04±0^{c}
	20	6,25±0,00^{c}	5,45±0,00^{c}	6,26±0,01^{c}	5,35±0,00^{d}
Vitamin C	5	4,93±1,12^{a}	0,15±0^{a}	2,13±0,97^{a}	0,05±0^{a}
	10	11,27±3,80^{b}	0,9±0^{b}	2,17±0^{a}	0,05±0^{a}
	15	13,85±0,49^{c}	1,42±0^{d}	3,66±0,49^{c}	0,10±0
	20	13,59±0^{c}	1,02±0^{c}	2,42±3,60^{b}	0,15±0^{c}

Assigneddifferentletters on the samecolumn are significantlydifferent at p <0.05 according to the Newman and Keuls test

The cooked Koto variety recorded a calcium content which decreased significantly from 51.40 to 45.7mg/100g MS (5th day of maturity) and from 53.35 to 50.87 mg/100g MS (20th days maturity). Into the Tomi variety, the levels decreased from 214 to 210.01 mg/100Gms (5th day of maturity) and from 217 to 213.01 mg/100g DM (20th day of maturity) after cooking. The Tomi variety has the highest calcium values.

The potassium contents of the cooked okra samples decreased significantly until the 20th day of maturity at the two varieties of okra. These levels ranged from 250.01mg/100g MS (5th day of maturity) to 243.08 mg/100g MS (20th day of maturity) and from 2.42 mg/100g DM (5th day of maturity) to 1.46 mg/100g DM.

Table 3 Evolution of some minerals according to the stages of maturity stages of 2 varieties of cooked okra

Minerals	stage of maturity	Varieties			
		Koto		Tomi	
		Fresh	Cooked	Fresh	Cooked
Fe	5	0,88±0,06^{a}	0,51±0,01^{a}	0,93±0,02^{a}	0,67±0,01^{a}
	10	0.92 ±0,07^{b}	0.66±0,02^{b}	0.97±0,01^{d}	0.71±0,02^{d}
	15	1.15±0,04^{c}	0.95±0,03^{c}	1.22±0,04^{b}	1.07±0,03^{b}
	20	1.11±0,03^{c}	0.71±0,03^{d}	1.17±0,03^{c}	0.98±0,04^{c}
P	5	15.21±0,01^{a}	10.47±0,05^{a}	12,68±0,4^{a}	8,66±0,3^{a}
	10	15.67±0,01^{b}	10.21±0,05^{b}	12.98±0,4^{b}	9.04±0,7^{b}
	15	16.07±0,02^{c}	11.54±0,03^{D}	14.68±0,3^{c}	10.67±0,6^{c}
	20	15.89±0,01^{d}	10.58±0,04^{C}	13.37±0,3^{d}	9.86±0,5^{d}
Ca	5	51.40±0,02^{a}	45.7±0,02^{a}	214±13^{a}	210,01±14^{a}
	10	52.06±0,02^{a}	49.9±0,02^{a}	216±12^{b}	211.6±12^{b}
	15	54.73±0,04^{b}	52.68±0,03^{b}	219.36±15^{c}	214±15^{d}
	20	53.35±0,03^{b}	50.87±0,04c	217±16^{d}	213.01±17^{c}
K	5	250.01±20^{a}	235.04±23^{a}	2.42±0,01^{a}	0.99±0,03^{a}
	10	252.2±20^{a}	238.7±24^{a}	2.78±0,02^{b}	1.05±0,07^{b}
	15	257.02±22^{b}	247.89±26^{b}	4.03±0,04^{c}	1.88±0,09^{c}
	20	256.15±21^{c}	243.08±25^{c}	3.59±0,03^{d}	1.46±0,06^{d}

Assigneddifferentletters on the samecolumn are significantlydifferent at p <0.05 according to the Newman and Keuls test

DISCUSSION

Cooking results in losses of most phenolic compounds (total polyphenols and flavonoids) of both varieties of okra (Koto and Tomi) depending on the stage of maturity.

This loss of phenolic compounds after cooking with water is due to the exposure of these two varieties of okra to high temperatures which could cause the destruction or volatilization of some highly unstable phenolic compounds. However, these values in total polyphenols and flavonoids obtained after cooking remain high. These phenolic compounds are molecules that provide more stability in the membranes of liver microsomes (Van Acker *et al.* 19988) and have an important role in the instinctive protection against oxidative stress with the contribution of other vitamins (Arbaayah and UmiKalsom, 2013). The losses in polyphenols could also be explained by the great facility of soluble polyphenols to be extracted during boiling, following a strong embrittlement of the cell walls by heat. Loss by cell burst facilitates the release of these polyphenolic compounds into the cooking water (Malika and Fouzia, 2011). Also, the drop in the phenol content could also be due to the leaching or thermolability of specific flavonoids (Yamaguchi *et al.* 2001). However, the presence of these biologically active compounds in boiled okra can attribute them therapeutic virtues.Also, the decrease in oxalate levels into the both varieties of cooked okra could be due to the thermolabile nature on the one hand and on the other hand to the damage of the plant cells during cooking; which leads to its elimination with water evaporation. Some authors have reported that cooking improves the bioavailability of nutrients significantly by destroying, inactivating or reducing antinutritional factors (Wang *et al.* 2008, Filli *et al.* 2010). These low levels of oxalate obtained into cooked okra would be beneficial for the consumer.The conservation of antioxidant activity into cooked okra is due to the bioconversion of highly unstable compounds in other more stable bioactive molecules and to the Maillard reaction products with antioxidant properties (Sengkhamparn and Phonkerd, 2014). Also, studies conducted by some authors suggest that thermal treatments could degrade endogenous oxidizing enzymes, which explains the increased rate of antioxidant activities by preventing enzymatic oxidation causing the neutralization of compounds with antioxidant activities in raw vegetable matter (Dewanto *et al.* 2002). The loss of protein content into the two varieties of boiled okra could be mainly attributed to the solubilization and diffusion of the proteins in the water released by the fruits under the influence of heat (Lund, 1997). On the other hand, this could be attributed to the Maillard reaction affecting the availability of amino acids and especially essential amino acids such as methionine, lysine and cysteine which are destroyed at high temperatures (180 ° C) (Cheftél *et al.* Kaanane *et al.* 1989). This Maillard reaction could also explain the decrease in reducing sugar levels after cooking. It allows the formation of smells, aromas and pigments characteristic of cooked, roasted and grilled foods (Marzocco *et al.* 2001). The decline in protein content into cooked okra may also be due to the Strecker reaction involving deamination and decarboxylation of amino acids (Machiels *et al.* 2000). As a result, the relatively low protein level into cooked okra may require supplementation with animal protein or legumes to impact protein-energy malnutrition (Uusiku *et al.* 2010).The loss of insoluble fibre content into cooked okra is related to a softening of the cell wall resulting in water absorption by fruit cells during boiling (Vodouhe *et al.* 2012). Thus, the decrease in insoluble fibre levels, observed during cooking, agrees with the works of Slavin (1987) and (Lintas *et al.* 1998). These works have showed a decrease in the insoluble fibre contentbecause of cooking. As regards soluble fibres, the increase observed during cooking is in agreement with the

work of Slavin (1987) and Lintas and Cappelloni (1998) who have shown that cooking leads to an increase in soluble fibre content and a decrease in the insoluble fibres content. Indeed, cooking changes the physical and chemical properties of plant cell walls affecting their performance as dietary fibre (Mc Dougall *et al.* 1996). Thus, the consumption of cooked okra could cover the daily need for soluble fibre which is estimated to be between 25 and 30g (Depezay, 2006) and would contribute to reducing the risks of hypertension, constipation, diabetes, colon cancer and breast (Ishida *et al.* 2000), since soluble fibre decreases the absorption of cholesterol and glucose in the blood (CFW, 2003) The decrease in mineral levels in our samples may be due to their leaching during cooking (Oboh, 2005). Despite this loss, the studied okra fruits could be considered as good sources of minerals at 45 min of cooking compared to other vegetables such as lettuce (0.4% DM) and spinach (0.7% MS) analysed by Salazar *et al.* (2006). Thus, calcium and phosphorus are very important in the growth and maintenance of bones, teeth and muscles (Turan *et al.* 2003). Iron is essential for the prevention of anaemia, which affects more than one billion people worldwide (Trowbridge and Martorell 2002). The increase in lipid content observed during water-cooking could be explained by the softening of the texture and walls of okra fruits. This would promote lipid release during extraction (Vodouhe *et al.* 2012). Gumbo fruits may be recommended for people on a low-fat or obese diet. However, the low lipid content of the gumbo studied is consistent with the work of Ejoh *et al.* (1996) and Onyeike *et al.* (2003) who have shown that fruit vegetables and okra leaves are not lipid sources. That corroborates the relatively low energy values of okra. This would explain their consumption as a condiment with staple starchy foods, usually in the form of porridge and their combination with various vegetable fats including palm oil and peanut paste during their preparation (Vainio-Mattila, 2000).

The decrease in vitamin C in cooked okras is due to their oxidation by factors such as heat (Ndawula, 2002). However, these losses are higher compared to those obtained by Fafunso and Bassir (1987) for cooked vegetables which amounts to about 66%. Vitamin C is a water-soluble antioxidant that promotes the absorption of iron by chelation or by keeping iron in reduced form (FAO, 2004). Consumption of cooked okra fruit vegetables could be supplemented by the consumption of tropical fruits to cover daily needs (40 mg/day) as recommended by FAO (2004)

CONCLUSION

The heat treatment has an impact on the nutritional value on the studied okra fruits. This treatment has led to a considerable reduction in the content of phytochemical and biochemical compounds excepted soluble fibres and lipids which have increased. The reduction of antinutritional factors will have a beneficial effect on the bioavailability of minerals and therefore for the health of the consumers. This treatment also led to an increase in the fibre content. It will be advantageous in facilitating the intestinal transit of the consumer. At the end of our study, the stage of maturity with the best nutritional profile after cooking is the stage 15 days of maturity for the two varieties of okra. Thus, high-fibre, low-fat, cooked okra samples could be recommended in a diet for weight reduction because of their low energetic value and be recommended for lipid-lowering and hypoglycaemic diets.

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