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Chemical and nutritional analysis of oil and plantain chips from palm olein enriched with extracts of green tea leaves (*Camellia sinensis*)

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Historic

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Abstract

The objective of this study was to evaluate the impact of methanolic extract from green tea leaves (TLE) on the oxidative stability of palm olein during deep-fat-frying and on the nutrient composition of plantain chips produced from it. Palm olein samples were respectively enriched with 1000, 1400 and 1800 ppm of extract; and 200 ppm of butylated hydroxytoluene (BHT) which served as positive control; while oil without additives served as negative control. A total of 15 frying cycles was done at 180°C for 3 min. Oil samples were collected fresh, at 1, 5, 8, 10 and 15 frying cycles for quality analysis. The evaluated parameters were the peroxide, anisidine, thiobarbituric acid, and iodine and total oxidation values (TOTOX). The plantain chips obtained after 5, 10 and 15 frying cycles were assessed for their proximate composition and mineral content using standards methods. Results showed that after 15 frying cycles, TLE at 1800 ppm protected palm olein from oxidation better than BHT as TOTOX of these oil samples were 25.54 and 28.24 respectively. A proximate and mineral composition analyses of chips revealed that in contrast to the samples made from oil without additives, those made from oil enriched with TLE showed low oil content and high carbohydrate, protein and mineral (phosphorus, calcium and magnesium) content. It can be concluded that green tea leaves extract is efficient in delaying palm olein alteration and increases the nutrient composition of plantain chips.

1. Introduction

Frying is one of the oldest culinary techniques used in the world. It is a very fast cooking method that offers the consumer food with attractive sensory qualities, hence its increasingly practiced in restaurants and households [1-2]. During frying, degradation reactions (hydrolysis, polymerisation, oxidation, isomerisation…) take place and lead to the formation of toxic compounds (free fatty acids, alcohols, aldehydes…) that alter not only the hygienic quality of the oil, but also its nutritional value [2]. To overcome this problem, many food industries use synthetic antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and ter-butylhydroquinone (TBHQ) as preservatives. However, these compounds offer little protection against thermoxidative degradation of the oil during deep frying and are responsible of health problems as they have been reported to be implicated in cardiovascular and carcinogenic diseases [3-4]. For these reasons, their use is increasingly contested around the world [5]. As a result, there is a growing interest in exploring natural sources with antioxidant activities.

Thus, several research studies have identified plants such as soursop (*Annona muricata*) flowers, green tea (*Camellia sinensis*) leave and coffea (*Coffea robusta*) leaves as containing significant amounts of phenolic compounds with good antioxidant activities [6-7-8]. In addition, Womeni et al. [7] reported that the methanolic extracts of old green tea leave contain significant amounts of phenolic compounds and flavonoids (53.51 mg GAE/g and 22.94 CE/g extracts). They also used high performance liquid chromatography to detect the presence of gallic acid, gallocatechin, epicatechin gallate and epigallocatechin gallate in these extracts, which are phenolic compounds with good antioxidant potential. In addition, these extracts were shown to offer good protection to palm olein during the Schaal oven test at 180°C [9]. Though similar studies have been carried out on evaluating the antioxidant activity of old green tea leaves, there is still lack of information on the ability of these extract to to limit oil degradation under real frying conditions. The use of natural antioxidants (*Salvia officinalis* and *Salvia rosmarinus* extracts)

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during deep frying tends to counteract the production of excess free radicals and the side effects on the quality of fried oils and products [10-11-12]. Old green tea leaves are mature leaves which are found in the base of tree, they are often eliminated when cleaning the farm. Therefore, they have attracted our attention due to the presence of high content of phenolic compounds known for their good antioxidant properties.

Plantain (*Musa x paradisiaca L.*) is a perennial plant native to tropical and subtropical areas. Its production represent a considerable economic challenge for the countries concerned, and its consumption helps to combat food insecurity because of its very important nutritional composition. Indeed, plantain contains vitamins (A, B, C, E, K), carbohydrates, proteins and minerals (phosphorus, potassium, calcium) [13]. Plantain is necessarily consumed after cooking, regardless of its stage of maturity. Therefore, boiling, braising or frying can be applied. Frying is widespread in Cameroon and is most often done on unripe plantain, with the aim of producing chips which are low water content foods that can be stored for a long period. They can be found in markets packaged in different sales formats, at tables during various ceremonies (funerals, mourning, weddings, birthdays, baptisms, etc.). Their production is simple, easy, less expensive and provides good profitability [14]. However, recent data have reported that, the nutritional composition of plantain chips varies not only according to the chemical composition of the oil used for its production, but also according to the frying conditions applied for this purpose [1-15]. This work was therefore carried-out to evaluate the impact of a methanolic extract from green tea leaves on the oxidative stability of palm olein during deep-fat-frying and on the nutrient composition of plantain chips produced from it.

2. Materials and methods

2.1 Materials

Old green tea leaves were harvested on the base of tree tea from Djuitsitsa tea plantation (Cameroon Tea Estate) located in Bafou, Menoua's Department, West Region, Cameroon, in September 2019. Palm olein without additives was purchased in November 2019 from SCS/RAFCA (Société de Raffinerie du Cameroun) located in Bafoussam, West Region, Cameroon. Unripe plantain (*Musa x paradisiaca L.*) of the *Mbouroukou* variety was purchased at the Casablanca market in the town of Bafoussam.

2.2 Methods

2.2.1 Preparation of methanolic extracts from green tea leaves

The extracts were prepared following the protocol of Djikeng et al. [9] with slight modifications. Old tea leaves were cleaned and oven dried at 50 °C for 48 h. They were ground and sieved using a 1 mm pore sieve. 250 g of powder was macerated in 1 L of methanol at room temperature with regular stirring for 48 h. Subsequently, the solution was filtered consecutively with Watman papers No. 4, and No. 1. The filtrate obtained was evaporated in a "BUCHI" evaporator at 40 °C under reduced pressure to remove the solvent. The extract was placed in an oven at 45 °C for 48 h in order to eliminate traces of solvent.

2.2.2 Phytochemical characterisation of extracts

2.2.2.1 Determination of total phenol content

The total phenolic content of the extracts was determined using the Folin-Ciocalteu colorimetric method as described by Gao et al. [16]. For this purpose, 20 µL of plant extract solution, 0.2 mL of Folin-Ciocalteu reagent and 2 mL of distilled water were mixed in a test tube and incubated at room temperature for 3 minutes. Subsequently, 1 mL of 20% sodium carbonate was added to the mixture. This was followed by a further incubation of 2 h at room temperature. The absorbance of the resulting solution was measured with a spectrophotometer at 765 nm. A gallic acid solution was used as a standard and the total phenolic content expressed as milligram gallic acid equivalents (GAE) per g extract.

2.2.2.2 Determination of flavonoid content

The determination of total flavonoids was done according to the method described by Marinova et al. [17]. To this end, after mixing approximately 0.1 mL of extract solution with 1.4 mL of distilled water in a test tube, 0.03 mL of a 5% sodium nitrite solution was introduced. After 5 minutes incubation at room temperature, 0.2 mL of a 10% $AlCl_3$ solution was added. After 5 minutes, 0.2 mL of a 10 % NaOH solution and 0.24 mL of distilled water were added. The absorbance of the resulting solution was measured at 510 nm using a spectrophotometer. A standard solution of catechin was prepared and the catechin content was expressed as catechin equivalent (CE) per gram of extract.

2.2.3 Oil samples preparation

The samples were prepared according to the method of Djikeng et al. [9]. The concentrated extracts were dissolved in 5 mL of methanol, and individually added into 1.5 kg of palm olein previously heated in the oven at 50 °C for 3h at three concentrations 1000; 1400 and 1800 ppm. Butylated hydroxytoluene (BHT) was used at its recommended concentration of 200 ppm [18] to compare the effectiveness of natural antioxidants present in the plant extracts. Palm olein without additives was prepared under similar conditions as described above and served as negative control. All samples were placed without cover in an oven for 48 h at 45 °C for evaporation of the solvent. It should be noted that the amounts of methanol used (5 mL/1.5 kg) for the preparation of the different samples was lower than 10 mg/kg or 50 mg/kg as recommended by the regulations [19].

2.2.4 Frying of plantain chips

Frying was carried out according to the protocol of Leong et al. [20] with slight modifications. 100 g of fresh oil from each sample was collected prior to the start of frying. A Rowenta electric fryer was used to fry 50 g of unripe plantains, previously cleaned and cut into thin slices of 3.83±0.28 mm thickness and 5.46±0.50 Cm diameter. Frying took place for 3 min at 180 °C, and the plantain chips were removed from the oil. The hot oil was left to cool at room temperature for 5 hours and 100 g of oil sample was

collected. The pre-cooled oil was used to fry another batch of plantain without adding new oil. Oil samples used in quality analysis were collected after 1, 5, 8, 10 and 15 frying cycles. All oil samples (stabilised and non-stabilised) were processed similarly. The determination of oxidation parameters was carried out on all oil samples. The plantain chips selected for the determination of proximate composition and mineral analysis were those obtained after 5, 10 and 15 frying cycles. In order to compare the nutritional value of plantain chips, a control sample of plantain was sliced and oven-dried at 40 °C for 24 hours.

2.2.5 Determination of oxidation parameters of oil samples

The determination of the peroxide value was done according to the spectrophotometric method of IDF 74 A: 1991 [21]. The official AOCS Cd 18-90 method [22] was used for determination of the p-anisidine value. The thiobarbituric acid value was determined according to the method of Drapper and Hadley [23]. The total oxidation value (TOTOX) of the samples was evaluated using the equation of Shahidi and Wanasundara [24]:

$$TOTOX = 2Peroxide\ value + p\text{-}anisidine\ value$$

The iodine value was determined according to the official method AOCS Cd 1-25 [22].

2.2.6 Determination of the proximate composition and mineral content of plantain chips

2.2.6.1 Proximate composition

The moisture, oil, ash and protein contents of plantain chip samples were determined using standard analytical methods described by the Association of Official Analytical Chemists procedures [25]. The moisture content was determined by drying the samples in an oven at 105 °C to constant weight. The ash content was determined by incinerating the sample for 20 h at 550 °C in a Carbolite Eurotherm muffle furnace. The nitrogen (N) content was analyzed by the micro-Kjeldahl method, and the protein content was calculated according to the equation: Protein % = N×6.25. The lipid content was determined using the Soxhlet method. Total carbohydrate content was determined by difference as reported by Onyeike et al. [26]. Fiber content was determined according to the protocol of Pauwels et al., [27]. Analyses were done in duplicate.

2.2.6.2 Mineral content

The mineral composition of plantain chips was determined by standard methods described by the Association of Official Analytical Chemists [25]. Four (04) macroelements (Ca, K, P, and Mg) and 02 microelements (Fe and Zn) were analyzed in the plantain chips samples. To this regard, ash samples were weighed and boiled with 10 mL of 20% HCl in a beaker and then filtered into a 100 mL standard flask to determine the mineral content. Calcium (Ca), magnesium (Mg), potassium (K), zinc (Zn) and iron (Fe) contents of the digested samples were determined by atomic absorption spectrophotometry using a Varian 220FS Spectra AA instrument (Varian, USA). Subsequently, phosphorus (P) was determined by a colorimetric spectrophotometric method using a UV spectrophotometer. Finally, standard mineral calibration curves were used to determine the mineral content of the plantain chip samples. Analyses were done in duplicate

2.2.7 Statistical analysis

The data obtained from this study were subjected to an analysis of variance (ANOVA) with the Waller-Duncan multiple comparison test to assess the statistical significance of the data expressed as mean±standard deviations. A probability value of less than 0.05 was considered statistically significant using SPSS version 23 software.

3. Results

3.1. Phytochemical characterization of the extracts

The total phenolic and flavonoid contents of the plant extract were found to be 157.36±0.78 mg GAE/g and 69.04±3.96 mg CE/g respectively.

3.2 Effect of extracts on oil quality

The effect of green tea leaves extracts on the oxidative stability of oil samples during frying of plantain chips (Table I) showed that the peroxide value significantly increased ($p<0.05$) in all palm olein samples from the beginning to the end of the process. Furthermore, a small increase in the peroxide value was observed in the oil supplemented with green tea leaves extracts compared to the positive control (OP+200BHT). In this regard, from the 10th frying cycle onwards, a significant decrease ($p<0.05$) in the peroxide value was observed in these oil samples.

Concerning the anisidine and thiobarbituric acid values, they also significantly increased with the number of frying cycles. However, at the 15th frying cycle, palm olein without additives (PO) showed a significant increase ($p<0.05$) in both parameters compared to oil samples enriched with both the plant extract and BHT. Supplementation of palm olein with 1800 ppm of extract led to a slight increase in 2-alkenals and 2,4-alkadienals in this sample but the values were not far from that of the positive control (OP+200BHT). Addition of the 1400 and 1800 ppm of extract contributed to a low formation of malondialdehydes in the oil during frying.

All oil samples exhibited significant ($p<0.05$) increase in total oxidation value (Table I) with the number of frying cycles. As previously observed with the anisidine value, during all the 15 frying cycles, all oil samples supplemented with the plant extract showed a slight increase in the total oxidation value compared to the negative control (PO). The lowest values of total oxidation value were recorded in palm olein supplemented with green tea leaves at concentration 1800 ppm.

Concerning the iodine value, it was found to decrease gradually with the number of frying cycles. However, the lowest decrease was observed in stabilised oil samples compared to the negative control (PO).

Table 1: Changes in palm olein quality during deep-fat frying of plantain chips

Oils quality indices	Samples	Frying cycles					
		0	1	5	8	10	15
Peroxide (meq O_2/Kg)	PO	$2.20\pm0.03^{d}_{A}$	$4.02\pm0.02^{e}_{B}$	$4.24\pm0.05^{d}_{BC}$	$5.60\pm0.02^{b}_{E}$	$5.27\pm0.20^{cd}_{D}$	$4.44\pm0.13^{a}_{C}$
	PO+200BHT	$1.15\pm0.00^{a}_{A}$	$1.63\pm0.00^{a}_{C}$	$1.55\pm0.02^{a}_{B}$	$3.73\pm0.02^{a}_{D}$	$4.97\pm0.01^{bc}_{E}$	$7.03\pm0.03^{d}_{F}$
	PO+1000TLE	$1.85\pm0.03^{c}_{A}$	$2.51\pm0.00^{c}_{B}$	$3.26\pm0.05^{b}_{C}$	$7.29\pm0.00^{e}_{E}$	$4.66\pm0.19^{ab}_{D}$	$4.80\pm0.27^{ab}_{D}$
	PO+1400 TLE	$1.16\pm0.12^{a}_{A}$	$3.63\pm0.06^{d}_{B}$	$3.91\pm0.01^{c}_{C}$	$6.81\pm0.09^{d}_{E}$	$5.46\pm0.04^{d}_{D}$	$5.27\pm0.05^{c}_{D}$
	PO+1800 TLE	$1.59\pm0.06^{b}_{A}$	$2.01\pm0.02^{b}_{B}$	$3.89\pm0.00^{c}_{C}$	$6.01\pm0.00^{c}_{F}$	$4.42\pm0.05^{a}_{D}$	$4.88\pm0.16^{b}_{E}$
***p*-anisidine**	PO	$9.31\pm0.32^{d}_{A}$	$15.15\pm0.07^{d}_{B}$	$24.55\pm0.33^{d}_{D}$	$21.05\pm0.04^{e}_{C}$	$25.42\pm0.17^{e}_{E}$	$33.81\pm0.13^{e}_{F}$
	PO+200BHT	$5.78\pm0.24^{c}_{A}$	$8.68\pm0.17^{c}_{B}$	$12.21\pm0.26^{bc}_{C}$	$12.14\pm0.07^{b}_{C}$	$13.17\pm0.02^{a}_{D}$	$14.16\pm0.07^{a}_{E}$
	PO+1000TLE	$5.59\pm0.06^{c}_{A}$	$5.39\pm0.07^{a}_{A}$	$12.39\pm0.15^{c}_{B}$	$15.59\pm0.40^{d}_{C}$	$15.82\pm0.20^{c}_{C}$	$24.04\pm0.01^{d}_{D}$
	PO+1400 TLE	$4.96\pm0.02^{b}_{A}$	$8.97\pm0.02^{c}_{B}$	$11.65\pm0.25^{b}_{D}$	$10.45\pm0.01^{a}_{C}$	$17.86\pm0.12^{d}_{E}$	$22.06\pm0.06^{c}_{F}$
	PO+1800 TLE	$2.89\pm0.05^{a}_{A}$	$7.19\pm0.15^{b}_{C}$	$6.54\pm0.00^{a}_{B}$	$13.78\pm0.08^{c}_{D}$	$15.19\pm0.19^{b}_{E}$	$15.78\pm0.02^{b}_{F}$
TBA value (ppm)	PO	$0.77\pm0.03^{c}_{A}$	$1.44\pm0.19^{c}_{B}$	$1.84\pm0.05^{d}_{C}$	$1.96\pm0.03^{d}_{CD}$	$2.34\pm0.29^{c}_{D}$	$3.40\pm0.15^{d}_{E}$
	PO+200BHT	$0.34\pm0.05^{b}_{A}$	$0.65\pm0.05^{b}_{B}$	$0.87\pm0.01^{b}_{C}$	$1.85\pm0.00^{d}_{E}$	$1.66\pm0.11^{b}_{D}$	$2.21\pm0.11^{b}_{F}$
	PO+1000TLE	$0.67\pm0.05^{c}_{A}$	$0.76\pm0.01^{b}_{A}$	$0.76\pm0.01^{a}_{A}$	$0.88\pm0.03^{b}_{B}$	$1.99\pm0.07^{bc}_{C}$	$2.54\pm0.00^{c}_{D}$
	PO+1400 TLE	$0.20\pm0.01^{a}_{A}$	$0.87\pm0.01^{b}_{B}$	$1.09\pm0.05^{c}_{C}$	$1.42\pm0.05^{c}_{D}$	$1.64\pm0.09^{b}_{E}$	$1.99\pm0.03^{b}_{F}$
	PO+1800 TLE	$0.24\pm0.00^{ab}_{A}$	$0.29\pm0.01^{a}_{A}$	$1.08\pm0.00^{c}_{D}$	$0.55\pm0.11^{a}_{B}$	$0.88\pm0.00^{a}_{C}$	$1.23\pm0.09^{a}_{D}$
TOTOX	PO	$13.71\pm0.24^{e}_{A}$	$23.19\pm0.03^{e}_{B}$	$33.04\pm0.43^{d}_{D}$	$32.25\pm0.10^{e}_{C}$	$35.98\pm0.23^{e}_{E}$	$42.71\pm0.40^{e}_{F}$
	PO+200BHT	$8.08\pm0.25^{c}_{A}$	$11.94\pm0.19^{c}_{B}$	$15.31\pm0.21^{b}_{C}$	$19.60\pm0.11^{a}_{D}$	$23.12\pm0.00^{a}_{E}$	$28.24\pm0.00^{b}_{F}$
	PO+1000TLE	$9.30\pm0.12^{d}_{A}$	10.42 ± 0.08^{a}	$18.92\pm0.04^{c}_{C}$	$30.17\pm0.40^{d}_{E}$	$25.14\pm0.58^{c}_{D}$	$33.64\pm0.54^{d}_{F}$
	PO+1400 TLE	$7.28\pm0.28^{b}_{A}$	$16.23\pm0.09^{d}_{B}$	$19.48\pm0.27^{c}_{C}$	$24.08\pm0.18^{b}_{D}$	$28.78\pm0.22^{d}_{E}$	$32.62\pm0.16^{c}_{F}$
	PO+1800 TLE	$6.08\pm0.08^{a}_{A}$	$11.22\pm0.11^{b}_{B}$	$14.33\pm0.02^{a}_{C}$	$25.81\pm0.10^{c}_{E}$	$24.05\pm0.29^{b}_{D}$	$25.54\pm0.35^{a}_{E}$
Iodine value (I_2/100g)	PO	$57.10\pm0.74^{a}_{C}$	$56.31\pm0.37^{a}_{BC}$	$55.90\pm0.00^{a}_{AB}$	$55.78\pm0.37^{a}_{AB}$	$55.25\pm0.37^{a}_{A}$	$54.99\pm0.00^{a}_{A}$
	PO+200BHT	$57.10\pm0.74^{a}_{B}$	$56.84\pm0.37^{ab}_{B}$	$56.70\pm0.38^{a}_{B}$	$56.31\pm0.37^{ab}_{AB}$	$56.04\pm0.00^{b}_{AB}$	$55.51\pm0.00^{ab}_{A}$
	PO+1000TLE	$57.36\pm0.37^{a}_{C}$	$56.84\pm0.37^{a}_{C}$	$56.70\pm0.38^{a}_{BC}$	$57.36\pm0.37^{c}_{C}$	$56.04\pm0.00^{b}_{AB}$	$55.51\pm0.00^{a}_{A}$
	PO+1400 TLE	$57.36\pm0.37^{a}_{A}$	$57.36\pm1.86^{a}_{A}$	$56.97\pm0.76^{a}_{A}$	$56.84\pm0.37^{bc}_{A}$	$56.57\pm0.00^{bc}_{A}$	$55.25\pm0.37^{a}_{A}$
	PO+1800 TLE	$57.63\pm0.00^{a}_{B}$	$57.89\pm0.37^{a}_{B}$	$56.70\pm0.38^{a}_{A}$	$56.57\pm0.00^{abc}_{A}$	$56.84\pm0.37^{c}_{A}$	$56.31\pm0.37^{b}_{A}$

n=2 (a-e) Values in the same column for each parameter with different superscripts are significantly ($p<0.05$) different; (A-F) Values in the same row with different letters differ significantly ($p<0.05$). PO =palm olein, PO+200BHT=palm olein supplemented with buthylated hydroxytoluene at 200 ppm, PO+1000TLE=palm olein supplemented with tea leaf extract at 1000 ppm, PO+1400TLE=palm olein supplemented with tea leaf extract at 1400 ppm, PO+1800TLE=palm olein supplemented with tea leaf extract at 1800 ppm, TBA value= thiobarbituric acid values, TOTOX=total

3.3 Effect of the addition of tea leaves extract in the frying oil on the proximate composition and mineral content of plantain chips

3.3.1 Proximate composition

Table 2 shows the effect of frying on the proximate composition of plantain chips. It can be observed that all plantain chips samples presented significantly ($p<0.05$) higher moisture contents compared to the oven-dried plantain (control). The moisture contents in the plantain chips varied between 7.48±0.29% and 10.00±0.00%. However, the moisture content in the control was 4.77±0.32%.

Concerning the lipid content, it was found to be zero in the control (oven-dried plantain) while significantly higher in fried chips. The highest lipid content (40.93±1.31%) was recorded in the plantain chips from palm olein without additives after 15 frying cycles (15PO) while the samples from 5 and 10 frying cycles with oils enriched with 1800 ppm extracts exhibited the lowest lipid content (25.35and 26.12% respectively).

The carbohydrate content of all plantain chips samples was significantly lower than the oven-dried control sample. The total carbohydrate in the control was 79.21±0.51% while it varied between 34.42±2.74 and 52.10±0.82% in fried chips.

Concerning the protein content, a significant decrease ($p<0.05$) in this parameter was registered in fried chip samples compared to the control. On the other hand, plantain chips from oils supplemented with the extract showed significantly ($p<0.05$) higher protein content compared to the negative and positive control.

The fibre content of plantain chips made from palm olein enriched with green tea leave extracts was similar ($p>0.05$) to that of the control (oven-dried plantain). Similar observations were made with the crude ash.

Table 2: Variations in proximate composition of plantain chips produced from oils supplemented with tea leaves extract

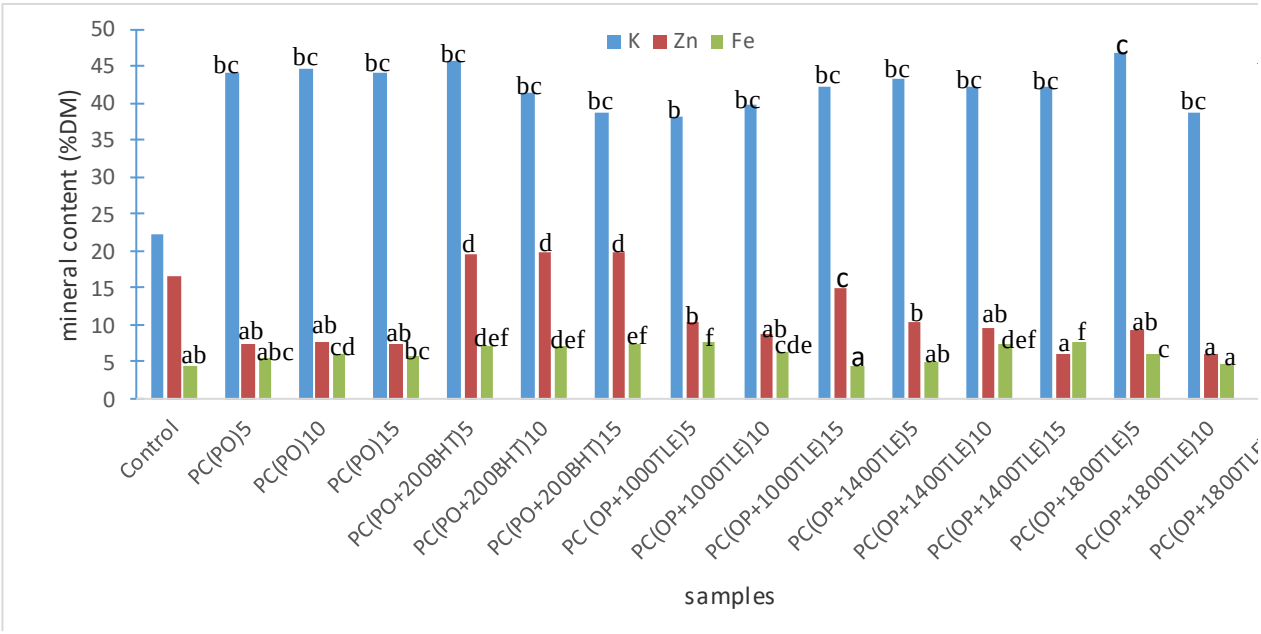
Samples	Parameters (%DM)					
	Moisture	Fat (%DM)	Carbohydrates	Proteins	Fibers	Ash
Control	4.77±0.32^{a}	0.00±0.00^{a}	79.21±0.32^{h}	5.18±0.09^{c}	8.83±0.09^{abc}	2.00±0.00^{a}
PC(PO)$_5$	8.57±0.34^{bcde}	35.49±1.90^{fg}	41.37±2.98^{bcd}	0.62±0.10^{a}	10.93±1.32^{cdef}	3.00±0.00^{a}
PC(PO)$_{10}$	8.71±0.53^{bcde}	37.51±2.28^{gh}	39.25±4.25^{ab}	0.60±0.10^{a}	10.92±1.32^{cdef}	3.00±0.00^{a}
PC(PO)$_{15}$	10.00±0.00^{f}	40.93±1.31^{i}	34.42±2.74^{a}	0.61±0.11^{a}	11.03±1.31^{cdef}	3.00±0.00^{a}
PC(PO+200BHT)$_5$	10.00±0.00^{f}	34.13±2.23^{efg}	39.23±3.81^{ab}	0.83±0.08^{a}	11.79±1.49^{ef}	4.00±0.00^{a}
PC(PO+200BHT)$_{10}$	8.11±1.37^{bcd}	32.95±1.60^{ef}	42.32±1.36^{bcd}	0.92±0.09^{a}	11.68±1.50^{def}	4.00±0.00^{a}
PC(PO+200BHT)$_{15}$	9.12±0.05^{def}	34.11±0.03^{efg}	39.63±1.66^{abc}	0.82±0.07^{a}	12.30±1.49^{f}	4.00±0.00^{a}
PC(OP+1000TLE)$_5$	8.83±0.36^{cdef}	27.36±0.76^{bc}	47.71±2.06^{efg}	2.92±0.12^{b}	10.16±1.54^{bcdef}	3.00±0.00^{a}
PC(OP+1000TLE)$_{10}$	9.54±0.64^{ef}	29.06±1.64^{cd}	44.60±2.49^{bcdef}	4.82±0.12^{c}	8.95±0.09^{bc}	3.00±0.00^{a}
PC(OP+1000TLE)$_{15}$	9.25±0.03^{def}	31.39±1.64^{de}	42.75±1.39^{bcde}	4.74±0.10^{c}	7.85±0.10^{ab}	4.00±0.00^{a}
PC(OP+1400TLE)$_5$	9.54±0.64^{ef}	27.42±2.60^{bc}	43.09±4.02^{bcdef}	7.80±0.80^{e}	9.13±0.03^{bcd}	3.00±0.00^{a}
PC(OP+1400TLE)$_{10}$	10.00±0.00^{f}	28.38±0.25^{bcd}	45.27±1.44^{cdef}	1.17±0.11^{a}	11.17±1.30^{cdef}	4.00±0.00^{a}
PC(OP+1400TLE)$_{15}$	9.21±0.17^{def}	28.23±0.46^{bcd}	52.10±0.82^{g}	1.25±0.09^{a}	6.19±0.09^{a}	3.00±0.00^{a}
PC(OP+1800TLE)$_5$	7.73±0.84^{bc}	25.35±1.36^{b}	47.32±0.92^{bcd}	6.57±0.52^{d}	9.02±0.12^{bc}	4.00±0.00^{a}
PC(OP+1800TLE)$_{10}$	7.48±0.29^{b}	26.12±0.76^{bc}	46.05±2.67^{def}	6.16±0.09^{d}	11.18±1.51^{cdef}	3.00±0.00^{a}
PC(OP+1800TLE)$_{15}$	8.33±0.00^{bcde}	29.21±1.43^{cd}	48.86±0.92^{fg}	1.24±0.11^{a}	9.34±0.39^{bcde}	3.00±0.00^{a}

n=2 (a-i) Values in the same column for each parameter with different letters differ significantly at ($p<0.05$). Control=oven-dried plantain, PC(PO)$_5$=plantain chips from 5 frying cycles with palm olein without additives, PC(PO)$_{10}$=plantain chips from 10 frying cycles with palm olein without additives, PC(PO)$_{15}$=plantain chips from 15 frying cycles with palm olein without additives, PC(PO+200BHT)$_5$=plantain chips from 5 frying cycles with palm olein supplemented with BHT at 200 ppm, PC(PO+200BHT)$_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with BHT at 200 ppm, PC(PO+200BHT)$_{15}$=plantain chips from 15 frying cycles with palm supplemented with BHT at 200 ppm, PC(OP+1000TLE)$_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, PC(OP+1000TLE)$_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, PC(OP+1000TLE)$_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, PC(OP+1400TLE)$_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, PC(OP+1400TLE)$_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, PC(OP+1400TLE)$_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, PC(OP+1800TLE)$_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, PC(OP+1800TLE)$_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, PC(OP+1800TLE)$_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, DM=dry matter.

3.5.2 Mineral composition of plantain chip samples

Figure 1 (A-B) shows the changes in mineral content of plantain chips produced with the control and stabilized oil samples. In general, regardless of the type of oil used and the number of frying cycles applied, the most abundant minerals were phosphorus and calcium. Potassium levels were significantly ($p<0.05$) higher in plantain chips prepared with stabilized oils compared to the control (oven-dried plantain). The samples obtained after 5 frying cycles with palm olein supplemented with 1800 ppm green tea leaves extract presented the highest potassium content (46.69±4.12 mg/100g DM). All plantain chips, except those made with BHT-enriched palm olein showed significantly ($p<0.05$) lower zinc contents compared to the control while the chips obtained from oils supplemented with the extract exhibited similar values in this parameter with the control. The iron content of plantain chips varied significantly ($p<0.05$) with the oil used. Plantain chips obtained after 15 frying cycles with palm olein containing 1000 ppm of extract presented the lowest iron content (4.44±0.07 mg/100g DM) while the highest concentration in this mineral (7.73±0.33 mg/100g DM) was observed in plantain chips produced after 15 frying cycles with palm olein supplemented with 1400 ppm of extract. The phosphorus content in plantain chips made from palm olein enriched with plant extracts is high and comparable ($p\geq0.05$) to the phosphorus content in control. Except for the chips obtained after 10 frying cycles with the oil samples enriched with 1000 and 1400 ppm of extract which showed significantly ($p<0.05$) high phosphorus contents compared to the control (oven-dried plantain). Both control and the plantain chips obtained with the different stabilised oil samples (BHT and extracts) had high calcium levels ($p<0.05$). Nevertheless, this mineral was abundant in

plantain chips obtained with palm olein enriched with green tea leaf extracts compared to the control. The highest value (194.73±5.84 mg/100g DM) was registered with plantain chips obtained after 10 frying cycles with palm olein enriched with 1800 ppm extract. The use of stabilized oils (BHT and extracts) for frying resulted in a significant increase in magnesium content in the chips compared to the control (oven-dried plantain).



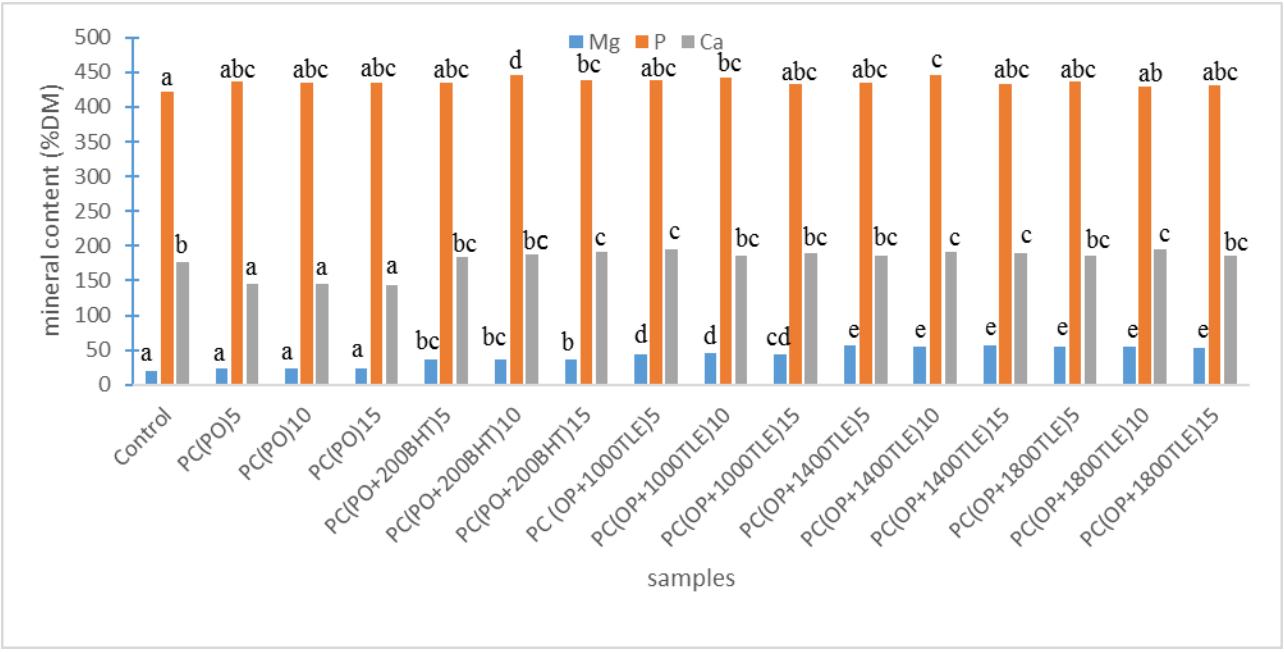


Figure 1 (A-B) : Changes in mineral composition of plantain chip produced with oils supplemented with green tea leaves extract.

n= (a-f) value of the same parameter with different letters differ significantly at ($p<0.05$). Control=oven-dried plantain, $PC(PO)_5$=plantain chips from 5 frying cycles with palm olein without additives, $PC(PO)_{10}$=plantain chips from 10 frying cycles with palm olein without additives, $PC(PO)_{15}$=plantain chips from 15 frying cycles with palm olein without additives, $PC(PO+200BHT)_5$=plantain chips from 5 frying cycles with palm olein supplemented with BHT at 200 ppm, $PC(PO+200BHT)_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with BHT at 200 ppm, $PC(PO+200BHT)_{15}$=plantain chips from 15 frying cycles with palm supplemented with BHT at 200 ppm, $PC(OP+1000TLE)_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, $PC(OP+1000TLE)_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, $PC(OP+1000TLE)_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1000 ppm, $PC(OP+1400TLE)_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, $PC(OP+1400TLE)_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, $PC(OP+1400TLE)_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1400 ppm, $PC(OP+1800TLE)_5$=plantain chips from 5 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, $PC(OP+1800TLE)_{10}$=plantain chips from 10 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, $PC(OP+1800TLE)_{15}$=plantain chips from 15 frying cycles with palm olein supplemented with tea leaf extract at 1800 ppm, K=potassium, Zn=zinc, Fe=iron, P=phosphorus, Ca=calcium, Mg=magnesium.

4. Discussion

4.1 Effect of tea leaves extracts on oil quality

Several investigations have already been carried-out to determine total phenolic and flavonoid contents of green tea leaves extract. Ndomou et al. [28] reported that extract of green tea leaves collected at Bafou (Menoua Division, Cameroon) has a total phenolic and flavonoid contents of 123.09±1.66 mg GEA/g and 18.49±2.06 mg CE/g of extract respectively. In the same line, Luo et al. [29] found that extract of green tea leaf collected in China was 243±7 mg GAE/g extract. The values obtained in this study were significantly higher than those obtained by Ndomou et al. [28] but lower than those of Luo et al. [29]. This difference can be attributed to the extraction conditions, climatic parameters and the location of sample collection, the variety and the state of maturity of the plant [7-30].

The increase in the peroxide value of oil samples reflects the increase in the production of hydroperoxides. This is because during frying, heat facilitates initiation of oxidation reactions which is characterised by the rapid formation of hydroperoxides after the propagation stage [4]. Therefore, the significant increase in peroxide value obtained with the positive control (OP+200BHT) marks the formation of hydroperoxide in this oil. On the other hand, the decrease in this parameter in oils samples enriched with plant extracts could be explained by the antiradical activity of the phenolic compounds present in the extracts. For this purpose, natural phenolic compounds are able to transform peroxyl and alkoxyl radicals into stable non-radical molecules [31]. However, hydroperoxides are unstable at high temperatures and decompose very quickly into secondary oxidation products [4], which makes the peroxide value an insufficient parameter to determine the rancidity status of an oil during frying. These results are in line with those of Solati and Baharin [32], who found that the peroxide value of oils enriched with black cumin (*N. sativa L*) extracts increased slightly during frying of potatoes chips.

The high level of secondary oxidation products in the negative control (PO) could be due to the absence of antioxidant in this sample. Indeed, hydroperoxides decompose spontaneously at high temperatures (150°C) to form secondary oxidation products which are responsible of the alteration of the olfactory and gustatory quality of food [33]. The slight increase in anisidine and thiobarbutiric acid values recorded in oils samples enriched with 1400 and 1800 ppm of plant extracts testifies the thermal resistance of the antioxidants present. These antioxidants could be responsible of the protective effect observed in palm olein during frying [7]. These results are in agreement with those obtained by of Che Man and Tan [9] who showed that rosemary and sage extracts effectively limit the formation of malondialdehydes in palm olein during frying of potatoes chips. These results also corroborate with the results of Houhoula et al. [34] who reported that oregano (*Origanum vulgare*) powders and extracts significantly reduce the anisidine value of cotton-seed oil during frying of potatoes chips.

The total oxidation value provides information on both the formation and decomposition of hydroperoxides and provides a better estimation of the overall rancidity of fat [7]. The high rancidity of the negative control (PO) observed can be attributed to the fact that this oil is free from antioxidants. Therefore, during frying, secondary oxidation compounds are formed at an exponential rate affecting the oxidative quality of the oil. Indeed, these extracts contain gallic acid, gallocatechin, epicatechin gallate and epigallocatechin gallate [7]. Then, it has been mentioned that gallate and epigallocatechin are the two main compounds responsible for their antioxidant activity [35]. These results are consistent with those of Solati and Baharin [32] who found that *N. sativa L* extract delayed the formation of hydroperoxides and secondary oxidation products in sunflower oil and palm olein during frying of potatoes chips.

The decrease in the iodine value observed in oil samples can be assigned to the destruction of the double bonds of unsaturated fatty acids by free radicals formed in the oil during frying [36]. The slight decrease in this parameter observed in stabilized oil samples compared to the negative control (PO) indicates the low degradation of unsaturated fatty acids in these oils as previously observed with the anisidine, thiobarbituric acid and total oxidation values. This could confirm the fact that these extracts protect palm olein from oxidation during frying. Djikeng et al. [9] reported similar observations during an accelerated storage of palm olein supplemented with green tea leaves methanolic extract in an electric air-dried oven at 180°C for six days. Past investigations have confirmed the ability of plant extracts to protect the double bonds of unsaturated fatty acids in vegetable oils during frying of chips [37-38].

4.2 Proximate composition

The moisture content of a food characterizes its shelf life. The moisture content of plantain samples ranged between 7.48±0.29 and 10.00±0.00%, which was lower compared to the values reported by Omolola et al. [15]. These authors showed that the moisture content of plantain chips made from three different vegetable oils varied between 12 and 14%. The low moisture content of the plantain chips obtained in this work shows that they can have good shelf-life.

The high lipid content recorded with plantain chips from palm olein without additives (PO) can be explained by the fact that this oil was more oxidised than the other oil samples. Indeed, the more degraded an oil sample is, the more viscous it is due to the formation of polymers and polar compounds which would lead to a strong absorption of the oil by the food [39]. Furthermore, according to Gamble et al. [40], when the fried food is removed from the fryer, a vacuum effect occurs due to the condensation of the steam, which increases the oil retention by the food at the same moment.

The low carbohydrate content observed in plantain chips when compared to that of the control could be due to the fact that, carbohydrates and proteins interact strongly with the oxidation

products produced during frying, leading to the formation of carcinogenic compounds. Also, carbohydrates are good substrates for non-enzymatic browning reactions and this decrease can be related to their condensation to proteins during frying. The reaction is catalyzed by high temperatures [36].

The values obtained in this work are comparatively lower compared to those reported by Adeyeye et al. [41]. This can be attributed to the differences in plantain varieties, types of oils used as well as frying conditions. The high protein content in the chips resulting from the oils enriched with plant extracts could be due to the fact that the phenolic compounds present in the extracts, by delaying the formation of free radicals, would have limited the alteration of the proteins. It is known that some free radicals formed in the oil during frying have the ability to complex proteins present in the food [42]. In addition, it was noticed that green tea leaves powder contain an average of 10.56% protein [28], which could have affected the protein content of the chips. These results are in agreement with those of Omolola et al. [15]. They found that frying leads to a reduction in protein content of plantain chips. Proteins are good substrates for non-enzymatic browning reactions and this chemical alteration process is facilitated by high temperatures. The decrease in protein observed can be attributed to their used as substrate in these reactions [1].

Crude fibers facilitate digestion, delays glucose absorption which gives it a hypoglycemic role, prevents colon cancer and also plays a cholesterol-lowering role. The results showed that the use of different oil samples in frying of plantain chips does not result in a significant change in fiber content when compared to the control. Similar observation was made by Omolola et al. [15].

4.3 Mineral content

The ash content of a food sample is closely related to its mineral composition. The concentrations of phosphorus, calcium, iron and zinc were found to be higher than those obtained by Adeyeye et al. [41]. Both magnesium and potassium values were significantly lower than the values reported by Omolola et al. [15]. These differences could be related to the genetic parameters, plantains varieties and frying conditions.

Potassium is involved in regulating osmotic pressure, facilitating membrane transport, nerve impulse transmission and muscle contraction. The recommended daily dose is 2.5 mg and its deficiency can cause muscle weakness and paralysis [43]. The highest potassium content was recorded in plantain chips produced with palm olein stabilized with 1800 ppm of extract after 5 frying cycles. The consumption of these plantain chips could be health beneficial.

Calcium is the major constituent of the skeletal structure and teeth, and it plays an important role in blood coagulation and in muscle contraction by reducing muscle excitability. This mineral in combination with vitamin D and phosphorus helps to combat rickets in children and osteoporosis in the elderly [44]. The calcium levels obtained in this work were significantly high compared to those obtained by Adeyeye et al. [41]. This could be attributed to factors previously mentioned.

Phosphorus uptake in the body is closely related to that of calcium. It is important in the fortification of bones and teeth, and also plays an important role in the course of metabolic reactions involving buffering the body fluids, as well as in energy storage and release [41]. The recommended daily intake for both adults and children is 750 mg/day [41]. Phosphorus levels in plantain chips made with palm olein fortified with green tea leaf extracts varied between 428,51±6,97 and 445,13±5,54 mg/100g. Consumption of these chips could help to limit phosphorus deficiency in both adults and children.

Magnesium is an activator of enzymes which require ATP for their function such as hexokinase, phosphatase, alkaline, fructokinase and adenyl-cyclase [38]. The recommended dietary intake is 360-420 mg/day depending on gender, age and physiological conditions [41]. The high levels observed in plantain chips made from oils supplemented with plant extract compared to those found in chips made from oil without antioxidants would be due to material transfer during frying. Interesting proportions of magnesium had been detected in green tea leaves powder [26].

Plantain chips from oils enriched with green tea leaves extract showed iron contents ranging from 4.44±0.07 to 7.73±0.33 mg/100g. Iron is essential for the body in small amounts, it is the basic constituent of haemoglobin and myoglobin, it is important in the diet of pregnant women as well as the elderly to prevent anaemia and other related diseases [40]. Iron also plays an unconditional role in haematopoiesis. The recommended daily intake varies between 9 and 30 mg depending on the age, sex and physiological condition of the individual [41]. Therefore, the use of these extracts when frying plantain chips could help provide more iron for good health.

Zinc is necessary in protein synthesis, strengthening the immune system and brain development. Its daily intake should be 10 to 20 mg/day [41]. The zinc concentrations found in this work (6.04±1.23-19.78±1.50 mg/100g of DM) with plantain chips samples are higher than those obtained by Adeyeye et al. [38] (2.41-3.44 mg/100g of DM) and lower than those of Omolola et al. [14] (17.33±0.07-39.17±0.00 mg/100g of DM). The above mentioned factors can explain the variations observed.

Conclusion

The objective of this study was to evaluate the impact of green tea leaves methanolic extract on the oxidative stability of palm olein during deep-fat-frying and on the nutrient composition of plantain chips produced from it. Results showed that green tea leaves extracts limit palm olein oxidation during frying of plantain chips at a similar level with BHT. Their effectiveness increased with their concentration. Palm olein enriched with tea leaves extracts preserves nutrient in plantain chips compared to the oil without extract. The minerals present in high concentrations in the plantain chips were calcium and phosphorus and the plant extract contributed to their increase. The use of these extracts not only protected the palm olein from oxidation during frying, but also preserved the nutrients of the plantain chips.

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