Journal of Food Processing & Technology
ISSN: 2157-7110

Research Article Open Access

Effect of Boiling and Roasting on the Lipids Quality of Pig Meat (*Longissimus dorsi* muscle) Enriched at Different Concentrations of *Allium sativum, Zingiber officinale, Allium cepa, Piper guineense* and *Ricinodendron heudelotii* Powders

Serge Cyrille Ndomou Houketchang[1], Tonfack Djikeng Fabrice[1,2], Tiwo Tsapla Cristelle[1], Teboukeu Boungo Gires [1], Dongmo Jean-Roger [1] and Womeni Hilaire M[1*]

[1]*Department of Biochemistry, University of Dschang, PO Box 67, Dschang, Cameroon*
[2]*School of Agriculture and Natural Resources, Institute of Buea, Catholic University, P.O. Box 563, Buea, Cameroon*

Abstract

Inappropriate diet and cooking techniques contribute to the reduction of nutrient quality of food and the rise of diet-related chronic diseases such as obesity. The present study was aimed at assessing the effects of boiling and roasting on the quality of the lipid of an adult *Large white* pig meat (*Longissimus dorsi* muscle) enriched with five spices at various concentrations. The proximate composition of uncooked meat was evaluated and the lipid quality was assessed by chemical characterization of oils extracted from the meat. Results revealed that meat had a high level in the water (66.08%); lipids (16.4%); proteins (15.95%); and a low level in ash (1.15%) and carbohydrates (0.42%). It also contains minerals such as magnesium (147.28 g/kg); sodium (2.88 g/kg); phosphorus (1.42 g/kg) and calcium (1.22 g/kg). All the treatments significantly ($p<0.05$) increased the acid value of fat extracted from pig meat; the values obtained agree with those recommended by the Codex Alimentarius. The treatments: Boiling+*Allium sativum* (5 g); Boiling+*Zingiber officinale* (3 g); Boiling+*Allium cepa* (3 g) and Boiling+mixture together reduced the alteration of double bonds and the formation of hydroperoxides. The principal component analysis reveals a relationship between TBARS value and acidity. Also, it shows that TBARS and peroxide values were more effective to induce lipids oxidation in meat products after cooking. In general, adding spices are more effective at limiting lipids oxidation of meat during cooking treatments compared to the control.

Practical applications: Boiling with *Allium sativum*, *Allium cepa* and *Zingiber officinale* powders could be applied in order to preserve the lipid quality of pig meat and health of consumers.

Keywords: Nutrition; Food technology; Spices; Pig meat

Introduction

Pig meat represents the world's most produced and consumed meat, with China occupying the first rank of this classification [1]. The meat constitutes a significant source of essential nutrients. It contains proteins of high quality, fats, vitamins (majorly vitamin B1) and minerals such as zinc and selenium. Its fatty acid composition varies according to the pieces [2]. According to habits and traditions, meat is always cooked before its consumption. Meat composition, as well as its physicochemical properties, undergo significant changes during heat treatment. It is well known that meat composition, especially its fat content, combined with a specific cooking methodology are among the factors that mostly affect the final quality of meat products [3]. Several authors pointed out that the cooking process affects the lipid composition of meat, especially the fatty acid content, by changing the nutritional value of cooked products in relation to raw samples [4,5]. In meat, the cooking process generates oxidation reactions of lipids and proteins and also generates free radicals and reactive oxygen species which are implicated in carcinogenesis, mutagenesis, inflammation, aging and cardiovascular diseases [6-8]. High temperature also catalyzes the reaction of Mallard which can lead to the formation of heterocyclic aromatic amines which are mutagens and are associated with certain cancers and cardiac damages [9]. In Africa, during cooking, spices are commonly used to enhance the organoleptic properties of foods. In Cameroon, meat is cooked with various amounts of aromatic spices and pepper in order to enhance the flavor, odor, and taste of the cooked meat according to the consumers demand. They do not take into consideration the other properties of these spices. It has been proven that spices contain a wide array of antioxidants including some vitamins, flavonoids, terpenoids, carotenoids, phytoestrogens, minerals, etc. which render them or their antioxidant components as preservative agents in food [10]. The antioxidant potential of many spices used in preserving oils and fats oxidation in foods has also been proven by many authors [11,12]. Mairesse et al. [13] showed that the addition of antioxidants from the vegetable origin in pigs foods, decrease the risk of oxidation of the pig raw coasts and cooked hams. However, the antioxidant activities of these compounds depend on their concentrations and at a certain concentration, they can impart prooxidant activities [14]. Despite various studies carried out on the effect of cooking on fatty acid composition [15-17], as far as we know, few data has been reported regarding the effect of different cooking methods on the quality of the lipid of pig meat enriched with various amount of recognized antioxidant spices from Cameroon. This work, therefore, was aimed at assessing the effects of two cooking methods on the quality of the lipid of pig meat enriched with five spices usually used for cooking in West-Cameroon.

Materials and Methods

Material

Spices like Garlic (*Allium sativum*), Ginger (*Zingiber officinale*),

***Corresponding author:** Womeni Hilaire M, Department of Biochemistry, University of Dschang, Dschang, Cameroon, Tel: +237233451381; E-mail: womeni@yahoo.fr

Received May 08, 2019; **Accepted** May 14, 2019; **Published** May 23, 2019

Citation: Houketchang Ndomou SC, Fabrice TD, Cristelle TT, Gires TB,Jean-Roger D, et al. (2019) Effect of Boiling and Roasting on the Lipids Quality of Pig Meat (*Longissimus dorsi* muscle) Enriched at Different Concentrations of *Allium sativum, Zingiber officinale, Allium cepa, Piper guineense* and *Ricinodendron heudelotii* Powders. J Food Process Technol 10: 802.

Onion (*Allium cepa*), white pepper (*Piper guineense*) and "Njansang" (*Ricinodendron heudelotii*) (Figure 1) and 5 kg of raw pig meat (*Longissimus dorsi* muscle) of a *Large white* race age of only 6 months were purchased at the local market located in Dschang, Menoua division, West region, Cameroon. The spices were identified at the national herbarium (Yaounde, Cameroon).

Methods

Sample preparation: At the laboratory, the hairs and bones of the raw pig meat were removed, the meat was cut into (25 to 50) g pieces and washed with water before they were randomly selected, weighed and divided into different portions: The first portion was dried in an electric oven for determination of its proximate composition. The second was used as control (not used for cooking) and the other was used for cooking (boiling and roasting) with and without spices. All spices used were dried at 45°C in an oven for 12 hours and crushed in powder before used.

Cooking:

Boiling: Meat (100 g) was boiled for 60 minutes at 95°C in 1300 ml of water. The procedure was repeated with other meat pieces by adding spices at concentrations of 1 g, 3 g and 5 g respectively. Then, samples were cooled at room temperature and kept for further analysis.

Roasting: Meat (100 g) was cut in small pieces (10 to 15) g, and roasted along with metal support with charcoal as a heating source (200 to 220)°C for a period of 15 minutes. The procedure was repeated with other meat pieces by adding spices at concentrations of 1 g, 3 g and 5 g. Only three spices were used for this treatment (*Allium sativum*, *Allium cepa,* and *Piper guineense*). The samples were cooled at room temperature and kept for further analysis.

Proximate composition of raw pig meat (*Longissimus dorsi*): Raw pig meat was dried in an electric oven at 50°C for 48 hours. The dried samples were crushed and stored in a desiccator for food-science analysis. Moisture, Crude protein, fat, ash, and total carbohydrate contents were respectively assayed by the IUPAC method [18] and AOAC official methods.

Lipid extraction: Fats were extracted from cooked and raw pig meat according to the method described by Bligh and Dyer [19]. About 100 g of meat samples were introduced in a grinding machine (Moulinex) to which 100 ml of chloroform and 200 ml of methanol were subsequently added. The mixture was ground for 5 minutes, followed by the addition of 100 ml of chloroform and 100 ml of water. The mixture was ground again for 1 minute and filtered. The final extraction was made by the addition of chloroform, this in order to respect the proportion of 2:2:1.8 for chloroform, methanol, and water, respectively. After separating the different phases in a funnel, the organic phase was collected and dried using sodium anhydrous. The organic solvent was then eliminated by evaporation on a rotatory evaporator at 45°C under reduced pressure. The extracted oils were stored in the refrigerator at 4°C for chemical analysis.

Chemical analysis of the extracted fats: Iodine value, peroxide value and an acid value of different oil samples were determined according to the AFNOR Official methods NFGA-203 and NFT 60-220 [20]. The thiobarbituric acid value was determined using the method recommended by the AOCS official method [21].

Statistical analysis: The tests were performed and results represented using mean ± standard deviations. All of these results have been submitted to the statistical analysis of variance (ANOVA) at 0.05% probability level. The Dunnett and his students Newmann and Keuls tests were used to compare mean using the software GraphPad-InStat, 2000. Pearson's correlation coefficients among the lipids quality parameters were calculated and the correlation matrix which was the primary data required for Principal Component Analysis generated. The principal components analyses were performed using the factor program of XLSTAT (2007) statistical package.

Results and Discussion

Proximate composition

Table 1 shows the proximate composition of raw pig meat sample. It appears that pig meat (*Longissimus dorsi*) contains a higher amount of water (66.08%), followed by lipid (16.4%) and proteins (15.95%), while, its carbohydrate and ash contents are relatively low. The obtained water

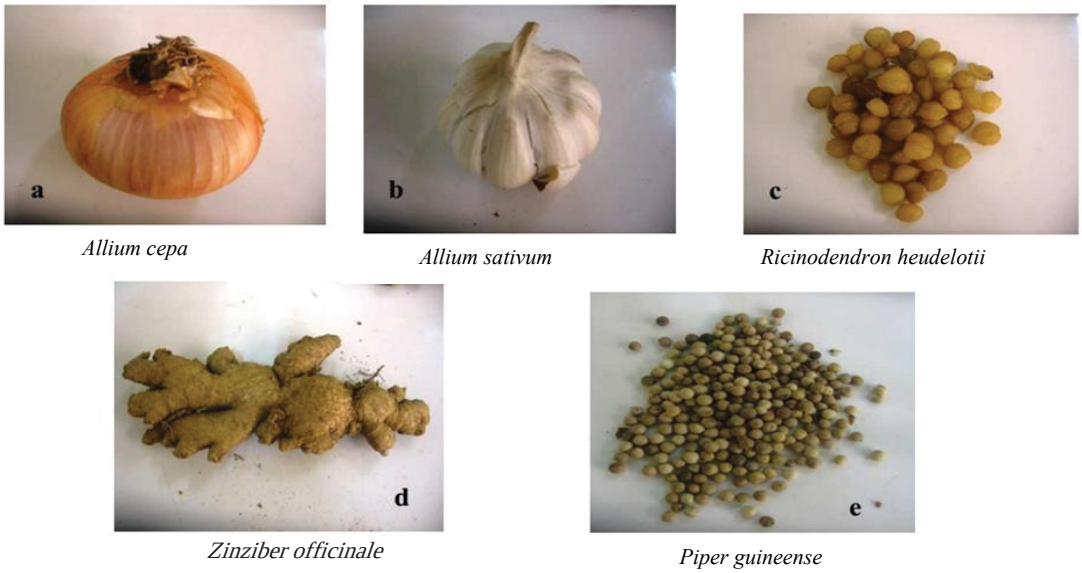

Figure 1: Spices used (generic names).

Parameters	Amount (%)
Moisture	66.08 ± 1.79[a]
Lipid	16.4 ± 0.03[b]
Protein	15.95 ± 0.23[b]
Ash	1.15 ± 0.12[c]
Carbohydrate	0.42 ± 0.02[c]
a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05)	

Table 1: Shows the coefficients for Henderson, Halsey, Oswin, Chung-Pfost and GAB equations of chamomile leaves for different drying systems.

content falls in the range defined by Cheftel et al. in muscles of meat which were 55% to 75%. The higher lipid content observed indicates that the *Longissimus dorsi* muscle may be classified as fatty meat [22] and this is due to the fact that the visible fat wasn't removed in this study. The protein content was lower to that obtained by Rinaldo and Mourot [23] on the *Longissimus dorsi* muscle (22.4%) and *Semi spinalis* muscle (18.2%) of pig meat and they attributed these differences to the feeding of animal and the types of muscle used. It is important to note that, because of its monogastric character, the feeding can affect the chemical composition of its meat [24]. The low carbohydrates content observed in Table 1 might be attributed to the process of glycogenosis that occurs after the slaughtering and causes the reduction of glycogen.

Mineral composition

The mineral composition (in g/kg) of raw pig meat is shown in Table 2. It appears that *Longissimus dorsi* muscle, the highest amount of mineral was magnesium (147.282 g/kg), and its content in other mineral was significantly lower. The sodium content obtained in this study (2.888 g/kg) was higher than that obtained by Dalle Zotte [25] on the rabbit meat, which varied in the range (0.370 to 0.490) g/kg. The Zn content (0.087 g/Kg) was comparable to that found by Ledoux [26], on the semi-membranous muscles of the pig meat (0.067 to 0.071) g/kg and this could be attributed to the presence of phytase in the animal feeding. Concerning the iron content, it was largely higher than that obtained by Ledoux [26] on the semi-membranosus muscle of the pig meat 0.026 g/kg. This difference could be the consequence of the part of the muscle tested, the age and the content in the myoglobin of the meat. Indeed Duterter et al. [27] observed an increment in the content of heminic iron and myoglobin rate 0.0038 g/kg and 1.156 g/kg respectively in pig meat of 9 months old compared to that of 6 months old which had the iron and myoglobin content of 0.0026 g/kg and 0.785 g/kg respectively.

Mineral	Amount (g/kg)
P	1.425 ± 0.025[c]
K	0.133 ± 0.000[c]
Na	2.888 ± 0.000[b]
Ca	1.227 ± 0.009[c]
Mg	147.282 ± 1.434[a]
Zn	0.087 ± 0.036[c]
Fe	0.089 ± 0.004[c]
a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05)	

Table 2: Mineral composition of pig meat.

Treatments	Iodine value (g I2/100g)
Raw	55.48 ± 1.11[a]
Bo	48.37 ± 2.69[b]
Bo+AS 1 g	53.89 ± 0.47[a]
Bo+AS 3 g	52.47 ± 2.22[a]
Bo+AS 5 g	47.23 ± 2.69[b]
Bo+ZO 1 g	43.42 ± 1.74[c]
Bo+ZO 3 g	49.14 ± 0.16[a]
Bo+ZO 5 g	48.97 ± 2.85[a]
Bo+AC 1 g	41.39 ± 1.42[c]
Bo+AC 3 g	51.99 ± 2.06[a]
Bo+AC 5 g	45.49 ± 3.81[b]
Bo+RH 1 g	48.5 ± 3.96[b]
Bo+RH 3 g	56.43 ± 0.15[a]
Bo+RH 5 g	48.34 ± 0.31[b]
Bo+ PG 1 g	32.19 ± 0.79[c]
Bo+PG 3 g	53.1 ± 0.31[a]
Bo+PG 5 g	49.98 ± 0.00[a]
Bo+mixture	53.10 ± 2.22[a]
a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05). Bo+AS 1 g=Boiling enriched with 1 g of *Allium sativum*, Bo+AS 3 g=Boiling enriched with 3 g of *Allium sativum*, Bo+AS 5 g=Boiling enriched with 5 g of *Allium sativum*; Bo+ZO 1 g=Boiling enriched with 1 g of *Zingiber officinale*, Bo+ZO 3 g=Boiling enriched with 3 g of *Zingiberofficinale* , Bo+ZO 5 g=Boiling enriched with 5 g of *Zingiber officinale*, Bo+AC 1 g=Boiling enriched with 1 g of *Allium cepa*, Bo+AC 3 g=Boiling enriched with 3 g of *Allium cepa*, Bo+AC 5 g=Boiling enriched with 5 g of *Allium cepa*; Bo+RH 1g=Boiling enriched with 1 g of *Ricinodendron heudelotii*, Bo+RH 3 g=Boiling enriched with 3 g of *Ricinodendron heudelotii*, Bo+RH 5g= Boiling enriched with 5 g of *Ricinodendron heudelotii*, Bo+G 1 g=Boiling enriched with 1 g of *Piper guineense*, Bo+PG 3 g=Boiling enriched with 3 g of *Piper guineense*, Bo+PG 5 g=Boiling enriched with 5 g of *Piper guineense*.	

Table 3: Iodine value of fat extracted from raw and boiled pig meat at various concentrations of spices.

Chemical analysis of oil samples

Iodine value: The iodine value (gI_2/100g) measures the level of unsaturation of lipids and is a good source for the alteration of such components. Tables 3 and 4 respectively present the effects of boiling and roasting on the iodine value of fat extracted from pig meat. No significant difference was observed between the raw sample and the following treatments: (Bo+AS) 1 g, (Bo+AS) 3 g, (Bo+ZO) 3 g, (Bo+ZO) 5 g, (Bo+AC) 3 g, (Bo+RH) 3 g, (Bo+PG) 3 g, (Bo+mixture) and (Ro+mixture). This would be due to the action of antioxidants components present in these spices that have limited the deterioration of double bonds of fatty acids in pig meat. The antioxidant activity of these spices might be attributed to the presence of some components such as polyphenols and flavonoids [28]. According to Sarni et al. [29] phenolic compounds intervene in the mechanism of interruption of the chain of propagation of lipids and the enzymes such as the lipoxygenase and the cycloxygenase which add an oxygen atom on the double bonds of lipids are inhibited by certain phenolic compounds. We also observed that a mixture of spices that limited the breakdown of double bonds of fatty acids can be due to the synergic effects of antioxidant components, in particular, the hydroxyl groups of polyphenols which can give their hydrogen to free radicals and stabilize them. These results agree with those of Kahouli [30] and Womeni et al. [12] who observed that certain spice powders limit the deterioration of the double bonds of the fatty acids in the oil of canola heated and in the raw soya oil respectively. The increase of the iodine value observed in the samples compared to the cooked meat without spices could be caused by the lack or the poor quantity of antioxidant components that can limit the oxidation of fatty acids in the oil.

Peroxide value: The level of formation of hydroperoxides on the fat extracted on pig meat after boiling and roasting is showed respectively in Tables 5 and 6. Only the treatments: (Bo+AS) 5 g, (Bo+ZO) 3 g, (Bo+AC) 3 g, (Bo+PG) 1 g and (Bo+mixture) showed a significant difference between the boiled sample (p<0.05) and no significant difference between the raw sample. This may be linked to the presence

Treatments	Iodine value (g I2/100g)
Raw	55.48 ± 1.11[a]
Ro	48.82 ± 1.11[b]
Ro+AS 1 g	43.74 ± 1.42[c]
Ro+AS 3 g	31.21 ± 1.27[c]
Ro+AS 5 g	48.34 ± 2.85[b]
Ro+AC 1 g	48.34 ± 1.58[b]
Ro+AC 3 g	45.36 ± 1.90[c]
Ro+AC 5 g	47.05 ± 1.58[c]
Ro+PG 1 g	45.64 ± 3.01[c]
Ro+PG 3 g	46.91 ± 1.42[c]
Ro+PG 5 g	44.09 ± 0.00[c]
Ro+mixture	51.20 ± 2.54[a]

a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p <0.05).
Ro+AS 1 g=Roasting enriched with 1 g of *Allium sativum*, Ro+AS 3 g=Roasting enriched with 3 g of *Allium sativum*, Ro+AS 5 g=Roasting enriched with 5 g of *Allium sativum*; Ro+AC 1 g=Roasting enriched with 1 g of *Allium cepa*, Ro+AC 3 g=Roasting enriched with 3 g of *Allium cepa*, Ro+AC 5 g=Roasting enriched with 5 g of *Allium cepa,* Ro+PG 1 g=Roasting enriched with 1 g of *Piper guineense*, Ro+PG 3 g=Roasting enriched with 3 g of *Piper guineense*, Ro+PG 5 g=Roasting enriched with 5 g of *Piper guineense*.

Table 4: Iodine value of fat extracted on raw and roasted pig meat at various concentrations of spices.

Treatments	Peroxide value (meq O2/kg)
Raw	5.00 ± 0.00[a]
Bo	12.50 ± 2.50[b]
Bo+AS 1 g	10.00 ± 0.00[b]
Bo+AS 3 g	10.00 ± 0.00[b]
Bo+AS 5 g	5.00 ± 0.00[a]
Bo+ZO 1 g	10.00 ± 0.00[b]
Bo+ZO 3 g	5.00 ± 0.00[a]
Bo+ZO 5 g	10.00 ± 0.00[b]
Bo+AC 1 g	10.00 ± 0.00[b]
Bo+AC 3 g	5.00 ± 0.00[a]
Bo+AC 5 g	15.00 ± 0.00[b]
Bo+RH 1 g	10.00 ± 0.00[b]
Bo+RH 3 g	15.00 ± 0.00[b]
Bo+RH 5 g	10.00 ± 0.00[b]
Bo+PG 1 g	7.50 ± 2.50[a]
Bo+PG 3 g	15.00 ± 0.00[b]
Bo+PG 5 g	10.00 ± 0.00[b]
Bo+mixture	7.50 ± 2.50[a]

a-b: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05).
Bo+AS 1 g=Boiling enriched with 1 g of *Allium sativum*, Bo+AS 3 g=Boiling enriched with 3 g of *Allium sativum*, Bo+AS 5 g=Boiling enriched with 5 g of *Allium sativum*; Bo+ZO 1 g=Boiling enriched with 1 g of *Zingiber officinale*, Bo+ZO 3 g=Boiling enriched with 3 g of *Zingiber officinale* , Bo+ZO 5 g=Boiling enriched with 5 g of *Zingiber officinale*; Bo+AC 1 g=Boiling enriched with 1 g of Allium cepa, Bo+AC 3g=Boiling enriched with 3 g of Allium cepa, Bo+AC 5 g=Boiling enriched with 5 g of Allium cepa, Bo+RH 1 g=Boiling enriched with 1 g of *Ricinodendron heudelotii* , Bo+RH 3g=Boiling enriched with 3 g of *Ricinodendron heudelotii*, Bo+RH 5 g= Boiling enriched with 5 g of *Ricinodendron heudelotii*; Bo+PG 1 g=Boiling enriched with 1 g of *Piper guineense*, Bo+PG 3 g=Boiling enriched with 3 g of *Piper guineense*, Bo+PG 5 g=Boiling enriched with 5 g of *Piper guineense*

Table 5: Peroxide value of fat extracted from raw and boiled pig meat at various concentrations of spices.

of antioxidant components in the corresponding concentration and other components such as minerals that have limited the formation of hydroperoxides in these samples. Indeed, Yin et al. [31] showed that *Allium sativum* is rich in selenium and organosulfur compounds which are powerful antioxidants, and so they might contribute to the antioxidant activity of garlic. Stoilova et al. [32] revealed that the extract

Treatments	Peroxide value (meq O_2/kg)
Raw	5.00 ± 0.00[a]
Ro	12.50 ± 2.50[b]
Ro+AS 1 g	10.00 ± 0.00[b]
Ro+AS 3 g	15.00 ± 0.00[b]
Ro+AS 5 g	17.50 ± 2.50[b]
Ro+AC 1 g	15.00 ± 0.00[b]
Ro+AC 3 g	20.00 ± 0.00[c]
Ro+AC 5 g	15.00 ± 0.00[b]
Ro+PG 1 g	12.50 ± 2.50[b]
Ro+PG 3 g	15.00 ± 0.00[b]
Ro+PG 5 g	20.00 ± 0.00[c]
Ro+mixture g	15.00 ± 0.00[b]

a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05)
Ro+AS 1 g=Roasting enriched with 1 g of *Allium sativum*, Ro+AS 3 g=Roasting enriched with 3 g of *Allium sativum*, Ro+AS 5 g=Roasting enriched with 5 g of *Allium sativum*; Ro+AC 1 g=Roasting enriched with 1 g of *Allium cepa*, Ro+AC 3 g=Roasting enriched with 3 g of *Allium cepa*, Ro+AC 5 g=Roasting enriched with 5 g of *Allium cepa,* Ro+PG 1 g=Roasting enriched with 1 g of *Piper guineense*, Ro+PG 3 g=Roasting enriched with 3 g of *Piper guineense*, Ro+PG 5 g=Roasting enriched with 5 g of *Piper guineense*

Table 6: Peroxide value of fat extracted from raw and roasted pig meat at various concentrations of spices.

of *Zingiber officinale* has a total phenolic content of 870.1 mg/g and its antioxidant activity measured by the method with the DPPH is very high (90.1%). Othman et al. [33] showed that extracts of *Allium cepa* have a total phenolic content of 53.43 mg GAE/100 g. In fact, these compounds intervene in the mechanism of interruption of the chain of propagation by yielding hydrogen to the peroxyl radicals and are capable to fixe metals of transition (Fe^{2+}, Cu^{2+}) which strongly accelerate lipids oxidation [30]. Red meat contains heme (Fe), which catalyzes the Fenton reaction, stimulating the production of reactive oxygen species (ROS) and the oxidation of Polyunsaturated fatty acids [34]. It was also noted that the antioxidant effects depend on the concentration of spices added; also, it was proven that the antioxidant activity is dependent on the concentration of antioxidants and at a certain concentration, the antioxidants can rather present prooxidant effects [14]. The increase of the peroxide value in all the treatments which undergone roasting could be due to the high temperature (200 to 220)°C that caused the volatilization of antioxidant components, the photo-oxidation process (because roasting was made in an open area), initiated by light in the presence of photosensitizers which can form radical capable to react with oxygen or can react directly with triplet oxygen to form singlet oxygen which in return react with unsaturated fatty acid to form hydroperoxides [35]. The results of the peroxide value obtained in this study are in line with those of Nabayo [36] who found a significant increase ($p<0.05$) of this value in the oils extracted from the worms of raffia (*Rhynchophorus phoenicis*) after boiling for 20 minutes (19.01 meq O_2/Kg) and roasting for 10 minutes (16.51 meq O_2/Kg) compared to the raw sample (8.25 meq O_2/Kg).

Thiobarbituric acid value: Secondary lipid oxidation was studied by the TBARS value, which is an index of malondialdehyde (MDA) concentration. MDA is one of the main end-products of lipid oxidation. The formation of TBARS after Boiling and Roasting is shown respectively in Tables 7 and 8. A significant increase in the TBARS value was observed in boiled and roasted samples compared to the raw sample. A high value was obtained with (Ro+AS) 3 g (3.32 ± 0.13 meq) MDA/Kg. The increase in the TBARS values after the treatment probably occurred due to the high temperature that promoted lipid peroxidation and increased malonaldehyde levels [37]. In contrast, no

Treatments	TBARS value (ppm)
Raw	0.188 ± 0.000[a]
Bo	0.396 ± 0.000[a]
Bo+AS 1 g	0.336 ± 0.024[a]
Bo+AS 3 g	0.392 ± 0.135[a]
Bo+AS 5 g	0.557 ± 0.034[a]
Bo+ZO 1 g	0.923 ± 0.166[b]
Bo+ZO 3 g	0.899 ± 0.130[b]
Bo+ZO 5 g	0.845 ± 0.207[b]
Bo+AC 1 g	1.082 ± 0.020[b]
Bo+AC 3 g	0.750 ± 0.128[b]
Bo+AC 5 g	1.317 ± 0.207[b]
Bo+RH 1 g	1.204 ± 0.352[b]
Bo+RH 3 g	0.488 ± 0.000[a]
Bo+RH 5 g	1.782 ± 0.187[c]
Bo+PG 1 g	1.560 ± 0.370[b]
Bo+PG 3 g	1.538 ± 0.216[b]
Bo+PG 5 g	1.345 ± 0.228[b]
Bo+mixture	1.155 ± 0.177[b]
Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05). Bo+AS 1 g=Boiling enriched with 1 g of *Allium sativum*, Bo+AS 3 g=Boiling enriched with 3 g of *Allium sativum*, Bo+AS 5 g=Boiling enriched with 5 g of *Allium sativum*; Bo+ZO 1 g=Boiling enriched with 1 g of *Zingiber officinale,* Bo+ZO 3 g=Boiling enriched with 3 g of *Zingiber officinale* , Bo+ZO 5 g=Boiling enriched with 5 g of *Zingiber officinale*; Bo+AC 1g=Boiling enriched with 1 g of *Allium cepa*, Bo+AC 3 g=Boiling enriched with 3 g of *Allium cepa*, Bo+AC 5 g=Boiling enriched with 5 g of *Allium cepa*, Bo+RH 1g=Boiling enriched with 1 g of *Ricinodendron heudelotii* , Bo+RH 3 g=Boiling enriched with 3 g of *Ricinodendron heudelotii*, Bo+RH 5 g= Boiling enriched with 5 g of *Ricinodendron heudelotii*; Bo+PG 1 g=Boiling enriched with 1 g of *Piper guineense*, Bo+PG 3 g=Boiling enriched with 3 g of *Piper guineense*, Bo+PG 5 g=Boiling enriched with 5 g of *Piper guineense*	

Table 7: TBARS value of fat extracted on raw and boiled pig meat at various concentrations of spices.

Treatments	TBARS value (ppm)
Raw	0.188 ± 0.000[a]
Ro	0.766 ± 0.027[b]
Ro+AS 1 g	1.417 ± 0.141[c]
Ro+AS 3 g	3.326 ± 0.138[d]
Ro+AS 5 g	1.669 ± 0.081[c]
Ro+AC 1 g	0.699 ± 0.047[b]
Ro+AC 3 g	1.619 ± 0.106[c]
Ro+AC 5 g	0.659 ± 0.037[b]
Ro+PG 1 g	1.176 ± 0.076[c]
Ro+PG 3 g	0.830 ± 0.107[b]
Ro+PG 5 g	0.810 ± 0.082[b]
Ro+mixture	0.725 ± 0.017[b]
a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05). Ro+AS 1 g=Roasting enriched with 1 g of *Allium sativum*, Ro+AS 3 g=Roasting enriched with 3 g of *Allium sativum*, Ro+AS 5 g=Roasting enriched with 5 g of *Allium sativum*; Ro+AC 1 g=Roasting enriched with 1 g of *Allium cepa*, Ro+AC 3 g=Roasting enriched with 3 g of *Allium cepa*, Ro+AC 5 g=Roasting enriched with 5 g of *Allium cepa*; Ro+PG 1 g=Roasting enriched with 1 g of *Piper guineense*, Ro+PG 3 g=Roasting enriched with 3 g of *Piper guineense*, Ro+PG 5 g=Roasting enriched with 5 g of *Piper guineense*	

Table 8: TBARS value of fat extracted on raw and roasted pig meat at various concentrations of spices.

significant difference (p>0.05) was observed in the TBARS value of Bo, (Bo+AS) 1 g, (Bo+AS) 3 g, (Bo+AS) 5 g and (Bo RH) 3 g samples, when compared with the raw sample. This could be due to rapid volatilization of aldehydes formed during these treatments or also by the action of antioxidants present in the spices added. According to Al-Kahtani et al. [38] meat products can be considered to be in a good conservation state, as far as oxidative changes are a concern, when they have less than 3 mg MDA/kg. Hence, all samples evaluated were suitable for consumption.

Acid value: Free fatty acid (FFA) content of the *Longissimus dorsi* muscle significantly increased by all the cooking methods evaluated, with a high value obtained after roasting (Table 9) than boiling (Table 10). The higher FFA content in cooked samples than the raw sample

Treatments	Acidity (% Oleic acid)
Raw	0.28 ± 0.00[a]
Ro	0.84 ± 0.00[c]
Ro+AS 1 g	0.56 ± 0.00[b]
Ro+AS 3 g	1.12 ± 0.00[d]
Ro+AS 5 g	0.70 ± 0.14[c]
Ro+AC 1g	0.70 ± 0.14[c]
Ro+AC 3 g	0.56 ± 0.00[b]
Ro+AC 5 g	0.56 ± 0.00[b]
Ro+PG 1 g	0.56 ± 0.00[b]
Ro+PG 3 g	0.70 ± 0.14[c]
Ro+PG 5 g	0.56 ± 0.00[b]
Ro+mixture	0.70 ± 0.14[c]
a-d: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05) Ro+AS 1 g=Roasting enriched with 1 g of *Allium sativum*, Ro+AS 3 g=Roasting enriched with 3 g of *Allium sativum*, Ro+AS 5 g=Roasting enriched with 5 g of *Allium sativum*; Ro+AC 1 g=Roasting enriched with 1 g of *Allium cepa*, Ro+AC 3 g=Roasting enriched with 3 g of *Allium cepa*, Ro+AC 5 g=Roasting enriched with 5 g of *Allium cepa*, Ro+PG 1 g=Roasting enriched with 1 g of *Piper guineense*, Ro+PG 3 g=Roasting enriched with 3 g of *Piper guineense*, Ro+PG 5 g=Roasting enriched with 5 g of *Piper guineense*	

Table 9: Acid value of fat extracted on raw and roasted pig meat at various concentrations of spices.

Treatments	Acidity (% Oleic acid)
Raw	0.28 ± 0.00[a]
Bo	0.56 ± 0.00[b]
Bo+AS 1 g	0.56 ± 0.00[b]
Bo+AS 3 g	0.56 ± 0.00[b]
Bo+AS 5 g	0.56 ± 0.00[b]
Bo+ZO 1 g	0.70 ± 0.14[c]
Bo+ZO 3 g	0.84 ± 0.00[c]
Bo+ZO 5 g	0.98 ± 0.14[c]
Bo+AC 1 g	0.56 ± 0.00[b]
Bo+AC 3 g	0.56 ± 0.00[b]
Bo+AC 5 g	0.56 ± 0.00[b]
Bo+RH 1 g	0.56 ± 0.00[b]
Bo+RH 3 g	0.56 ± 0.00[b]
Bo+RH 5 g	0.98 ± 0.14[c]
Bo+PG 1 g	0.70 ± 0.14[c]
Bo+PG 3 g	0.98 ± 0.14[c]
Bo+PG 5 g	0.84 ± 0.00[c]
Bo+mixture	0.70 ± 0.14[c]
a-c: Values are represented as means ± standard deviations (n=3). Values with different letters differ significantly (p<0.05) Bo+AS 1 g=Boiling enriched with 1 g of *Allium sativum*, Bo+AS 3 g=Boiling enriched with 3 g of *Allium sativum*, Bo+AS 5 g=Boiling enriched with 5 g of *Allium sativum*; Bo+ZO 1g=Boiling enriched with 1 g of *Zingiberofficinale*, Bo+ZO 3 g=Boiling enriched with 3 g of *Zingiberofficinale*, Bo+ZO 5 g=Boiling enriched with 5 g of *Zingiberofficinale*; Bo+AC 1 g=Boiling enriched with 1 g of *Allium cepa*, Bo+AC 3 g=Boiling enriched with 3 g of *Allium cepa*, Bo+AC 5 g=Boiling enriched with 5 g of *Allium cepa*; Bo+RH 1 g=Boiling enriched with 1 g of *Ricinodendronheudelotii*, Bo+RH 3g=Boiling enriched with 3 g of *Ricinodendronheudelotii*, Bo+RH 5 g= Boiling enriched with 5 g of *Ricinodendronheudelotii*, Bo+ PG 1 g=Boiling enriched with 1 g of *Piper guineense*, Bo+PG 3g=Boiling enriched with 3 g of *Piper guineense*, Bo+PG 5 g=Boiling enriched with 5 g of *Piper guineense*	

Table 10: Acid value of fat extracted from raw and boiled pig meat at various concentrations of spices.

could be explained by the breakdown of ester bonds of triglycerides by the heating process. During boiling, heating water catalyzes the hydrolysis of ester bonds of triglycerides and releases free fatty acids in the oil. Similar results were obtained by Hernandez et al. [39] who showed that boiling of the pig meat increases its free fatty acid content and they attributed that to the hydrolysis of triglycerides. While during roasting, the very high temperature involves a further breakdown of ester bonds of triglycerides present in oil by thermolysis. Labuza [40] revealed that a very high temperature could lead to a higher FFA content due to strong hydrolysis of esters bonds of triglycerides and Lin et al. [41] showed that the percentage of acidity on minced pork increases with temperature and the duration of cooking. However, all these acidities are lower than those recommended by the Codex Alimentarius [42] which is 2% for the unrefined olive oils and 1.25% for the molten lard and edible tallow. We can also observe that the antioxidant activity of spices do not play a significant role here and no data has shown the link between antioxidant activity and acid value.

Correlations between lipids quality parameters by principal component analysis: Table 11 presents the correlations between the lipids quality parameters assessed in this study. There is a significant negative correlation ($p<0.05$, $r=-0.66$) between iodine value and TBARS value. While, a significant positive correlation ($p<0.05$, $r=0.66$) has obtained between acidity and TBARS value of oils. This means that an increase in free fatty acid increases the formation of secondary oxidative products such as malondialdehyde in oils extracted from different meat samples. Findings of this study are in agreement with Maqsood and Benjakul [43] which revealed that free fatty acids involved of hydrolysis of triglycerides are more susceptible to undergo oxidative reactions in order to form primary and secondary oxidative products such as short-chain aldehydes, ketones, and other oxidized compounds that may adversely affect the overall quality and acceptability of meat and meat products. Figure 2 indicates the principal components analysis of lipids quality parameters of oils extracted from uncooked and cooked pig meat. This analysis discriminated the cooking treatments according to the lipids quality parameters analyzed in this study. The first principal component (PC1) is explained by TBARS value and is identified with eigenvalues of 2.14. The second principal component

Variables	Iodine value	Peroxide value	TBARS value	Acidity
Iodine value	1			
Peroxide value	-0.147	1		
TBARS value	-0.662*	0.264	1	
Acidity	-0.281	0.106	0.622*	1

Table 11: Correlations between lipids quality parameters.

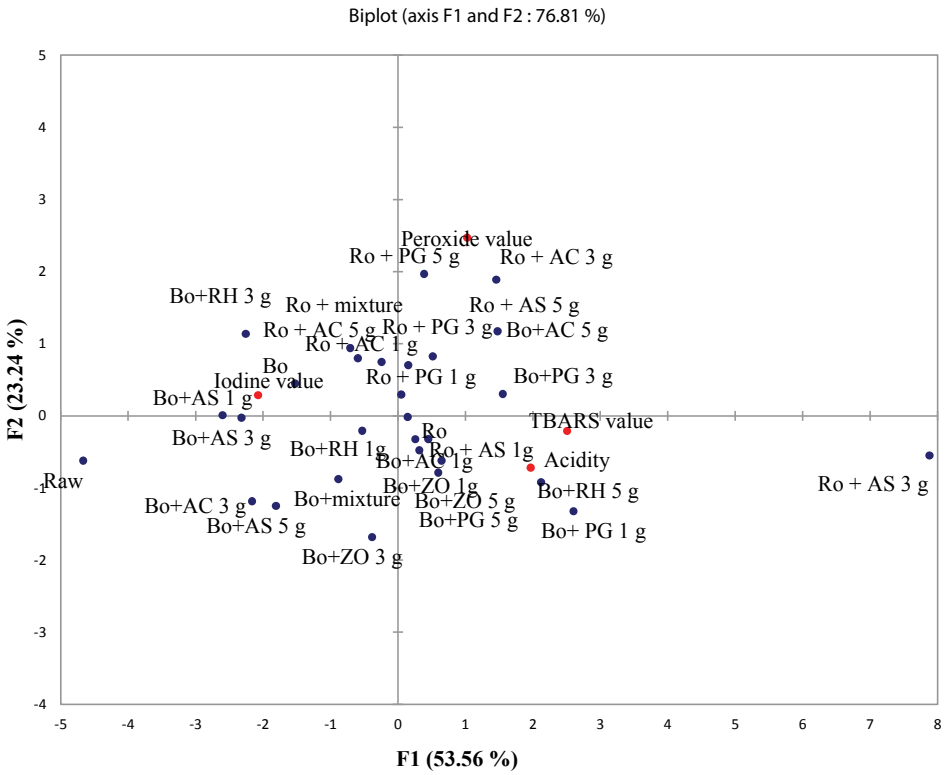

Figure 2: Principal Component Analysis (PCA) of lipids quality parameters extracted from pig meat.
Bo+AS (1 g)=Boiling enriched with 1 g of *Allium sativum*, **Bo+AS (3 g)**=Boiling enriched with 3 g of *Allium sativum*, **Bo+AS (5 g)**=Boiling enriched with 5 g of *Allium sativum,* **Bo+ZO (1 g)**=Boiling enriched with 1 g of *Zingiberofficinale*, **Bo+ZO (3 g)=**Boiling enriched with 3 g of *Zingiberofficinale*, **Bo+ZO (5 g)**=Boiling enriched with 5 g of *Zingiberofficinale,* **Bo+AC (1 g)**=Boiling enriched with 1 g of *Allium cepa*, **Bo+AC (3 g)**=Boiling enriched with 3 g of *Allium cepa*, **Bo+AC (5 g)**=Boiling enriched with 5 g of *Allium cepa,* **Bo+RH (1 g)**=Boiling enriched with 1 g of *Ricinodendronheudelotii*, **Bo+RH (3 g)**=Boiling enriched with 3 g of *Ricinodendronheudelotii*, **Bo+RH (5 g)**=Boiling enriched with 5 g of *Ricinodendronheudelotii,* **Bo+G (1 g)**=Boiling enriched with 1 g of *Piper guineense*, **Bo+PG (3 g)**=Boiling enriched with 3 g of *Piper guineense*, **Bo+PG (5 g)**=Boiling enriched with 5 g of *Piper guineense,* **Ro + AS (1 g)**=Roasting enriched with 1 g of *Allium sativum*, **Ro+AS (3 g)**=Roasting enriched with 3 g of *Allium sativum*, **Ro+AS (5 g)**=Roasting enriched with 5 g of *Allium sativum,* **Ro+AC (1 g)**=Roasting enriched with 1 g of *Allium cepa*, **Ro+AC (3 g)**=Roasting enriched with 3 g of *Allium cepa*, **Ro+AC (5 g)**=Roasting enriched with 5 g of *Allium cepa,* **Ro+PG (1 g)**=Roasting enriched with 1 g of *Piper guineense*, **Ro+PG (3 g)**=Roasting enriched with 3 g of *Piper guineense*, **Ro+PG (5 g)**=Roasting enriched with 5 g of *Piper guineense* .

(PC2) is explained by peroxide value with eigenvalues of 0.93. The two factors combined accounted for 76.81% with 53.56% and 23.24% for the first and second axis respectively. By this observation, TBARS and peroxide value could be more susceptible to affect the lipids quality of pig meat during cooking. In addition, this figure shows that cooked meats supplemented with spices are situated at the positive site of the biplot meaning that they more are able to preserve lipids quality of meat during cooking. Kumar et al. [44] showed that some natural phenolic compounds derived from plants and spices function as both primary and secondary antioxidants which can prevent lipids oxidation in foods. Radha Krishnan et al. [45] studied the antioxidant effect of 4 different spice extracts (1%), (*Syzygium aromaticum*, *Cinnamomum cassia*, *Origanum vulgare,* and *Brassica nigra*), in raw chicken meat stored at 4°C during 15 days. They revealed that these spice extracts were very effective against lipid oxidation, and their combination increased the antioxidant potential most likely because of the synergistic effects of various antioxidative factors.

Conclusion

This study showed that boiling with spices, especially *Zingiber officinale, Allium sativum, and Allium cepa respectively known as* Ginger, garlic and onion, limited the degradation of double bonds and the formation of hydroperoxides in oil extracted from pig's meat. It also revealed that the activities of spices depending on their concentration and at a certain level, they can impart prooxidant activities. Therefore, as ingredients generally used in cooking, they can be used moderately in order to ensure the quality of meat and preserve the health of consumers.

References

1. United States Department of Agriculture, Foreign Agricultural Service (USDA) (2012) Livestock and poultry: World Markets and Trade, annual.
2. Corneau L, Gagnon H, Lebeuf Y (2006) Porc et sanglier institut des nutraceutiques et des aliments fonctionnels (INAF), Université Laval, Québec, Canada, p: 40.
3. Serrano A, Librelotto J, Cofrades S, Sánchez-Muniz FJ, Jiménez-Colmenero F (2007) Composition and physicochemical characteristics of restructured beef steaks containing walnuts as affected by cooking method. Meat Sci 77: 304-313.
4. Badiani A, Stipa S, Bitossi R, Gatta RR, Vignola G, et al. (2002) Lipid composition, retention and oxidation in fresh and completely trimmed beef muscles as affected by common culinary practices. Meat Sci 60: 169-186.
5. Ndomou SCH, Tonfack DF, Tiwo CT, Teboukeu GB, Womeni HM (2018) Effects of culinary treatments on lipids quality, proximate composition and mineral content of broilers meat fed with rations supplemented with powders of *Camellia sinensis*, *Annona muricata*, and *Zingiber officinale*. Food Research 2: 356-367.
6. Shahidi F (1997) Natural antioxidants: an overview, In Natural Antioxidants, Chemistry, Health Effects and Applications, Ed. F. Shahidi, AOCS Press Campaign, Illinois, USA, pp: 1-10.
7. Pezzuto JM, Park, EJ (2002) Autoxidation and antioxidants in encyclopedia of pharmaceuticals technology Eds; Swarbrick J and Boylan JC, Marcel Dekker, Inc., New York, 1: 97-113.
8. Siddhuraju P, Becker K (2003) Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of drumstick tree (*Moringa oleifera Lam*.) leaves. J Agric Food Chemi 51: 2144-2155.
9. Skog KI, Johannsson MA, Jagerstad MI (1998) Carcinogenic heterocyclic amines in model systems and cooked foods: A review on formation, occurrence, and intake. Food Chem Toxicol 36: 879-896.
10. Calucci L, Pinzono C, Zandomeneghi M, Capocchi A, Ghiringhelli S, et al. (2003) Effects of gamma irradiation on the free radical and antioxidant contents in nine aromatic herbs and spices. J Agric Food Chem 51: 927-934.
11. Chung TW, Chen CJ, Gao S, Chou CP (2012) Effects of synthetic antioxidants and garlic extracts on the stability of crude jatropha oil. Int J Biol Eco Env Sci 1: 2277-4394.
12. Womeni HM, Tonfack DF, Tiencheu B, Linder M (2013) Antioxidant potential of methanolic extracts and powders of some Cameroonian spices during accelerated storage of soybean oil. Adv Biol Chem 3: 304-313.
13. Mairesse G, Benet M, Mourot J (2010) Prévention de l'oxydation des lipides de la viande de porc enrichie en acides gras n-3 par l'ajout d'antioxydants naturels dans la ration. 13èmes Journées Sciences du Muscle et Technologie de la Viande. Clermont-Ferrand, France, pp: 55-56.
14. Cillard J, Cillard P (1980) Pro-oxidant effect of alpha-tocopherol on essential fatty acids in aqueous media. Ann Nutr Aliment 34: 579-592.
15. Badiani A, Montellato L, Bochicchio D, Anfossi P, Zanardi E, et al. (2004) Selected nutrient contents, fatty acid composition, including conjugated linoleic acid, and retention values in separable lean from lamb rib loins as affected by external fat and cooking method. J Agric Food Chem 52: 5187-5194.
16. Maranesi M, Bochiccio D, Montellato L, Zaghini A, Pagliuca G, et al. (2005) Effect of microwave cooking or broiling on selected nutrient contents, fatty acid patterns and true retention values inseparable lean from lamb rib loins, with emphasis on conjugated linoleic acid. Food Chem 90: 207-218.
17. Sarriés MV, Murray BE, Moloney AP, Troy D, Beriain MJ (2009) The effect of cooking on the fatty acid composition of longissimus muscle from beef heifers fed rations designed to increase the concentration of conjugated linoleic acid in the tissue. Meat Sci 81: 307-312.
18. IUPAC (union Internationale de Chimie pure appliquée) (1979) Méthodes d'analyses des matières grasses. 6èmeédition, an international digest of health legislation. 46: 241.
19. Bligh EG, Dyer WJ (1959) A rapid method for total lipid extraction and purification. Can J Biochem Physiol 37: 911-917.
20. AFNOR (Association Française De Normalisation) (1981) Recueil des normes françaises des corps gras. Graines oleagineuses, produits dérivés. 2nd edition, p: 438.
21. AOCS (American Oil Chemists' Society) (1987) Official methods and recommended practices of the AOCS. 5th Edition, Campaign, IL (USA), Recommended Practice (Ca 5c-87).
22. Feinberg M, Favier JC, Ireland RJ (1987) Répertoire général des aliments: table de la composition des corps gras. Tec and Doc, INRA; Paris, France, p: 160.
23. Rinaldo D, Mourot J (2002) Effects of tropical climate and season on growth, the chemical composition of muscle and adipose tissue and meat quality in pigs. Anim Res 50: 507-521.
24. Mourot J, Hermier D (2001) Lipids in monogastric animal meat. Reprod Nutr Dev 4: 109-118.
25. Dalle ZA (2004) Le lapin doit apprivoiser le consommateur: Advantages diététiques. Viandes et Produits Carnés 23: 161-167.
26. Ledoux D, Knight C, Becker B, Baile C (1993) Effects of a porcine somatotrophin implant on tissue mineral status of finishing pigs exposed to the thermoneutral or cold environment. J Anim Sci 71: 2180-2186.
27. Duterter C, Darré S, Duplantier I, Dutoya D, Hargous JM, et al. (2007) Comparaison de la qualité de viandes de porcs de six et neuf mois d'âge. INPAQ, Consortium du jambon de Bayonne, France, pp: 233-241.
28. Agbor GA, Moumbegna P, Oluwasola EO, Nwosu LU, Njoku RCC, et al. (2011) Antioxidant capacity of some plant foods and beverages consumed in the Eastern region of Nigeria. Afr J Tradit Comple Altern Med 8: 362-369.
29. Sarni-Machado, Cheynier PV (2006) Les polyphénols en agroalimentaire, Ed. Lavoisier (Tec and Doc), Paris, France, pp: 300-398.
30. Kahouli I (2010) Effet antioxydant d'extraits de plantes (laurus nobilis l.,rosmarinus officinalis, origanum majorana, oléa europea l.) dans l'huile de canola chauffée. Université Laval Québec, pp: 16-52.
31. Yin M, Hwang S, Chan K (2002) Nonenzymatic antioxidant activity of four organosulfur compounds derived from garlic. J Agri Food Chem 50: 6143-6147.
32. Stoilova I, Krastanov A, Deney P, Gargova S (2007) Antioxidant activity of a ginger extract (*Zingiber officinale*). Food Chem 102: 764-770.
33. Othman SFC, Idid SZ, Koya SK, Rehan AM, Kamarudin KR (2011) Antioxidant

study of garlic and Red Onion: A comparative study. Pertanika J Trop Agric Sci 34: 253-261.

34. Van Hecke T, Jakobsen LM, Vossen E, Guéraud F, De Vos F, et al. (2016) Short-term beef consumption promotes systemic oxidative stress, TMAO formation and inflammation in rats, and dietary fat content modulates these effects. Food Funct 7: 3760-3771.

35. Eymard S (2003) Mise en évidence et suivi de l'oxydation des lipides au cours de la conservation et de la transformation du chinchard (Trachurustrachurus). Université de Nantes, Ecole polytechnique de l'Université de Nantes, France, p: 217.

36. Nabayo CEM (2009) Influence des traitements culinaires et de conservation des vers de raphia (rhynchophorus phoenicis) sur la qualité des lipides et des protéines. Thèse de Master of Science. Faculté des Sciences, Université de Dschang, Cameroun, p: 90.

37. Weber J, Bochi VC, Ribeiro CP, Victorio AM, Emanuelli T (2008) Effect of different cooking methods on the oxidation, proximate and fatty acid composition of silver catfish (*Rhamdiaquelen*) fillets. Food Chem 106: 140-146.

38. Al-Kahtani HA, Abu-Tarboush HM, Bajaber AS, Atia M, Abou-Arab AA, et al. (1996) Chemical changes after irradiation and post-irradiation storage in tilapia and Spanish mackerel. J Food Sci 91: 729-733.

39. Hernandez P, Navarro JL, Toldra F (1999) Lipids of pork meat as affected by various cooking techniques. Food Sci. Technol Int 5: 501-508.

40. Labuza TP (1974) Effect of dehydration and storage on nutrient retention in foods. Food Technol 27: 20-26.

41. Lin HS, Lee JY, Ke BC (2011) Effect of cooking method and storage on the quality of minced pork. J Agri Sci Technol 1: 1249-1256.

42. Codex alimentarius (1999) Programme mixte FAO/OMS sur les normes alimentaires, rapport de la XVIe session du comité du codex sur les graisses et les huiles. Londres (Royaume-Uni), p: 70.

43. Maqsood S, Benjakul S (2011) Comparative studies on molecular changes and pro-oxidative activity of hemoglobin from different fish species as influenced by pH. Food Chem 124: 875-883.

44. Kumar Y, Yadav DN, Ahmad T, Narsaiah K (2015) Recent trends in the use of natural antioxidants for meat and meat products. Compr Rev Food Sci Food Saf 14: 1-17.

45. Radha Krishnan K, Babuskin S, Azhagu Saravana Babu P, Sasikala M, Sabina K, et al. (2014) Antimicrobial and antioxidant effects of spice extracts on the shelf life extension of raw chicken meat. Int J Food Microbiol 171: 32-40.