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## EFFECT OF COOKING AND EXTRACTION METHOD ON OLEAGINOUS CUCURBIT SEED OILS QUALITY

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### ABSTRACT

In sub-Saharan Africa, *Lagenaria siceraria* seeds are cooked before consumption. Cooking seed may alter their chemical composition, leading to changes in their health benefits. Thus, this study aimed at determining the effect of cooking of *L. siceraria* seeds on their edible oil quality. Heat treatments were performed as roasted (100 and 125 °C) and boiled (10, 35, 60 and 90 min). Then oils were extracted with petroleum ether solvent and hot-water flotation process. Peroxide and acid index, and fatty acids composition were evaluated. With the hot-water flotation process, roasting and boiling had no significant effect on acid index and fatty acids composition. However, peroxide values varied from 1.1 to 2.9 meqO<sub>2</sub> kg<sup>-1</sup> oil. The highest peroxides values were revealed at 90 and 60 min, respectively, in seeds roasted at 100 and 125 °C. With solvent extraction, roasting and boiling affected only peroxide values and fatty acids composition. The highest peroxide values were reached after 10 min of ebullition of roasted seeds, both at 100 and 125 °C. Saturated and polyunsaturated fatty acid contents increased after 10 min of boiling of seeds roasted at 100 and 125 °C; then decreased to reach the initial content. But, the monounsaturated fatty acids content decreased after 10 min of boiling, and then increased to reach the initial content. The highest values of peroxides and polyunsaturated fatty acids contents were observed with solvent extraction compared to hot-water flotation method. Cooking of *L. siceraria* seeds does not alter the quality of their oil; solvent extraction makes their oil highly unstable.

**Key Words:** Fatty acids, *Lagenaria siceraria*, quality indexes

### RESUME

En Afrique subsaharienne, les graines de *Lagenaria siceraria* sont consommées cuites. La cuisson des graines peut altérer leur composition chimique, entraînant des changements quant à leurs bienfaits pour la santé. Ainsi, cette étude visait à déterminer l'effet de la cuisson des graines de *L. siceraria* sur

la qualité de leurs huiles. Les traitements thermiques ont été effectués: torréfaction (100 et 125 ° C) et ébullition (10, 35, 60 et 90 min). Les huiles ont, ensuite, été extraites avec l'éther de pétrole et par un procédé de flottation à l'eau chaude. L'indice de peroxyde et d'acide ainsi que la composition en acides gras ont été évalués. Avec le procédé de flottation à l'eau chaude, la torréfaction et l'ébullition n'ont eu aucun effet sur l'indice d'acide et la composition en acides gras. Cependant, les valeurs de peroxyde variaient de 1,1 à 2,9 méqO<sub>2</sub>.kg d'huile. Les valeurs les plus élevées de peroxydes ont été révélées à 90 et 60 min respectivement dans les graines torréfiées à 100 et 125 ° C. Avec l'extraction par solvant, la torréfaction et l'ébullition n'ont affecté que les valeurs de peroxyde et la composition en acides gras. Les valeurs de peroxyde les plus élevées ont été atteintes après 10 min d'ébullition des graines grillées à 100 et à 125 °C. Les teneurs en acides gras saturés et polyinsaturés ont augmenté après 10 min d'ébullition des graines torréfiées à 100 et 125 °C puis ont diminué pour atteindre leurs teneurs initiales lorsque le temps d'ébullition a augmenté. Mais, la teneur en acides gras monoinsaturés a diminué après 10 minutes d'ébullition, puis a augmenté pour atteindre la teneur initiale. Les valeurs les plus élevées des teneurs en peroxydes et en acides gras polyinsaturés ont été observées avec l'extraction par le solvant comparé à la méthode de flottation à l'eau chaude. Cuire les graines de *L. siceraria* n'altère pas la qualité de leur huile ; l'extraction par le solvant rend leur huile hautement instable.

*Mots Clés:* Acides gras, *Lagenaria siceraria*, indice de qualité

## INTRODUCTION

*Lagenaria siceraria* (Molina) Standl. belongs to cucurbitaceous family, is one of the most widely distributed and consumed cucurbit in both rural and urban areas in sub-Saharan Africa. *Lagenaria siceraria* is the most widely cultivated oleaginous cucurbit for its high agronomic potential (Achigan Dako *et al.*, 2006). It exhibits the richest macronutrient contents, and contains 40 % proteins and 54 % fat (Loukou *et al.*, 2011). Loukou *et al.* (2011) have revealed that in *L. siceraria* oils, polyunsaturated fatty acids rate varies between 56.41 and 66.70 %. The high content of essential fatty acids in this crop contributes to human tissues development (Ntsomboh-Ntsefong *et al.*, 2016). In addition, Milind and Satbir (2011) reported that *Lagenaria siceraria* seed oil has several beneficial health effects.

*Lagenaria siceraria* seeds are consumed as a soup thickener called *pistache* soup in Côte d'Ivoire, and *egussi* soup in Nigeria. In Côte d'Ivoire, to prepare this sauce the seeds are decorticated, roasted, ground made into dough, and boiled. The seeds are also grilled for snack (Morimoto and Mvere, 2004). However, heat treatment like baking, grilling

and pan frying can deteriorate fats and oils. But, most information on *L. siceraria* concern raw seeds and they do not reflect cooked seed nutritional quality (Badifu, 2001). So, it is necessary to evaluate cooked seed composition, particularly variation in oil during cooking process. Indeed, oil qualities are determined by their fatty acids composition, which may be affected by heat treatment.

Onyeike and Acheru (2002) showed that the high degree of unsaturation in the oil led to the low resistance to oxidative rancidity. According to Richardsa *et al.* (2005), lipid oxidation is probably the most important factor affecting the quality of edible oils. The hydroperoxides produced by lipid oxidation can be decomposed into various smaller molecules such as aldehydes, ketones, alcohols and carboxylic acids. Some of these volatile compounds impact the favour even at very low concentrations and degrading. Oils or foods become either unpalatable or unhealthy to consumption. Moreover, the ingestion of rancid lipids has been linked to the development or exacerbation of many diseases, such as atherosclerosis, cataracts, diarrhea, kidney disease and heart disease, and can cause cellular membrane damage, nausea,

neurodegeneration and carcinogenesis (Richardsa *et al.*, 2005).

This study was conducted to evaluate the nutritional quality of the oil from *Lagenaria siceraria* roasted and boiled seeds in order to ascertain their suitability for consumption.

## MATERIALS AND METHODS

In 2012, seeds of oleaginous, *L. siceraria* were extracted from mature fruits collected from experimental farm of Nangui Abrogoua University, Cote d'Ivoire. The seeds were sundried for 7 days and shelled manually to obtain the kernels. The sundried seeds were divided in two categories of unprocessed (kept as control) and cooked (roasted and boiled).

**Roasting process.** The seeds (1200 g) were roasted in an air-oven at temperatures of 100 and 125 °C for 25 min (Badifu, 2001). During roasting, kernels were turned every after 5 min using spatula for uniform roasting. After roasting, the seeds were ground using a laboratory crusher (Culatti, France) and stored in an airtight plastic container at -20 °C for further analysis.

**Boiling process.** One hundred grammes of roasted seeds of *L. siceraria* were put in beaker containing 500 ml of boiled distilled water. The cooking was carried out at 98 °C during 10, 35, 60 and 90 min; while stirring occasionally using Spatula. This technique was performed in duplicate. After boiling, the samples were cooled at room temperature (20 -25 °C). Two lots were constituted. Each lot contained raw seeds, roasted seeds at 100 and 125 °C; and boiled seeds during 0, 35, 60 and 90 min. Boiled samples of both lots were lyophilised using lyophiliser.

**Oil extraction.** The oils from the first lot were extracted with petroleum ether, using a Soxhlet apparatus (AOAC, 2000). The extracted oils were packaged in brown bottles for analysis (named solvent extraction). The oils of the

second lot were extracted by hot-water flotation according to Warra (2011) with some modifications. A hundred ml of boiling water were added to 20 mg of sample and stirred for 15 min. After cooling the upper oil layer was collected, dried by heating and also packaged in dark glass bottles in refrigerator.

**Chemical analyses.** Peroxide value (Cd 8b-90) and acid value (NF T60-204) were determined using AOCS (1997) methods. Fatty acids composition was also evaluated; whereby 10 mg of oil were first converted in their methyl esters (FAMES) with a mixture of boron trifluoride (BF<sub>3</sub>) and methanol (140 mg ml<sup>-1</sup>), according to the method of Morrison and Smith (1964). The extracted FAMES were dissolved in pure hexane for gas chromatography analysis (HP 6890, Agilent technologies Brussels, Belgium) with flame ionisation detection. One µl aliquot of FAME sample was injected onto a Varian CP 9205 (Sint-Katelijne Waver, Belgium) capillary column (30 m length, 0.25 mm diameter, 0.25 µm film thickness). A standard mixture of 37 fatty acids (Supelco, Bellefonte, PA, USA) was used for identification. The identification was confirmed by gas chromatography/mass spectrometry.

**Statistical analysis.** All chemical analyses data were statistically analysed by one way analysis of variance (ANOVA). Means were compared by LSD test. The analyses were performed using Statistica 7.1 software (StatSoft, Poland).

## RESULTS

**Roasting and boiling.** Table 1 presents peroxide and acid index values of *L. siceraria* oils from roasted and boiled seeds extracted with solvent; while Table 2 presents their fatty acids composition. Results showed that the cooking processes had significant effects on peroxide values and fatty acids composition. On the other hand, there was no significant

TABLE 1. Peroxide and acid values of *Lagenaria siceraria* oil extracted with solvent during seeds processing

Parameters	Untreated seeds (control)	Cooking process				Codex norm for cold pressed and virgin oils						
		Roasting at 100 °C during 25 min		Roasting at 125 °C during 25 min								
		Boiling times (min)										
		0	10	35	60	90						
PV (meq O <sub>2</sub> kg <sup>-1</sup> oil)	3.3±0.1 <sup>c</sup>	3.3±0.1 <sup>c</sup>	4.5±0.1 <sup>a</sup>	4.1±1.0 <sup>ab</sup>	3.8±0.0 <sup>bc</sup>	3.1±0.1 <sup>c</sup>	2.3±0.1 <sup>d</sup>	4.1±0.1 <sup>ab</sup>	3.2±0.0 <sup>e</sup>	3.1±0.1 <sup>e</sup>	3.5±0.2 <sup>bc</sup>	< 15 meq O <sub>2</sub> kg <sup>-1</sup>
AI (g KOH kg <sup>-1</sup> oil)	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	< 4 g KOH kg <sup>-1</sup>

Different letters within the same line indicate significant differences among cooking process (P<0.05). PV = Peroxide Index, AI = acid index

effect on acid index. Roasting at 125 °C had significantly reduced peroxide values of oils extracted with the solvent. On the other hand, peroxide values significantly increased until certain boiling time beyond which they decreased. The highest peroxide values were reached after 10 min of ebullition of roasted seeds for both 100 °C (4.49 meq O<sub>2</sub> kg<sup>-1</sup> oil) and 125 °C (4.12 meq O<sub>2</sub> kg<sup>-1</sup> oil).

For fatty acids composition, the results have showed that the major fatty acids in *L. siceraria* seed oils were linoleic acid (574 to 614,8 g kg<sup>-1</sup>), oleic acid (142.7 to 185.9 g kg<sup>-1</sup>), and palmitic acid (153.4 to 162.1 g kg<sup>-1</sup>) (Table 2). Roasting (100 and 125°C during 25 min) and boiling (during 10, 35, 60 and 90 min) had a significant effect on fatty acids composition of the oils. The variation in fatty acids composition occurred with the change of peroxide values. Saturated and polyunsaturated fatty acids contents increased after 10 min of boiling; then returned to the original contents when the boiling time increase for seeds roasted at 100 and 125 °C. The monounsaturated fatty acids content decreased after 10 min of boiling (185.7 to 142.7 g kg<sup>-1</sup>) and then returned to the original contents.

Table 3 presents peroxide and acid index values of *L. siceraria* oils from roasted and boiled seeds extracted by hot-water flotation and Table 4 presents their fatty acids composition. The denomination “nd” was attributed to samples whose oils could not be collected after hot-water flotation process.

During cooking, results showed no change in acid index values, but there was a significant effect in peroxide values. In these oils, peroxide values significantly increased until certain boiling time (90 min for seeds roasted at 100 °C and 60 min for seeds roasted at 125 °C); beyond which they decreased. Indeed, the highest peroxides values were revealed at 90 min for seeds roasted at 100 °C (2.94 meq O<sub>2</sub> kg<sup>-1</sup> oil) and 60 min for seeds roasted at 125 °C (2.31 meq O<sub>2</sub> kg<sup>-1</sup> oil). The results have also showed that the major fatty acids in these oils were linoleic acid (568.1 to 600.5 g kg<sup>-1</sup>), oleic acid (166.2 to 182.2 g kg<sup>-1</sup>), and

TABLE 2. Fatty acids composition of *Lagenaria siceraria* oil extracted with solvent during seeds processing

Fatty acid (g kg <sup>-1</sup> )	Untreated seeds (control)	Cooking process									
		Roasting at 100 °C during 25 min					Roasting at 125 °C during 25 min				
		Boiling times (min)					Boiling times (min)				
		0	10	35	60	90	0	10	35	60	90
C16:0	153.4±0.4 <sup>c</sup>	154.3±0.5 <sup>c</sup>	158.4±0.5 <sup>ab</sup>	152.9±0.1 <sup>c</sup>	155.0±1.9 <sup>bc</sup>	153.8±0.2 <sup>c</sup>	155.2±1.0 <sup>bc</sup>	162.1±3.5 <sup>a</sup>	154.5±0.2 <sup>bc</sup>	154.5±0.6 <sup>bc</sup>	155.0±0.8 <sup>bc</sup>
C18:0	76.4±1.0	75.2±0.2	74.7±0.2	76.1±0.0	70.2±4.3	73.6±0.3	74.8±0.5	76.3±0.2	75.6±0.0	74.8±0.5	74.6±0.3
C20:0	3.5±0.1	3.5±0.1	3.3±0.0	3.5±0.1	3.8±0.2	3.8±0.3	3.5±0.0	3.4±0.0	3.6±0.0	3.4±0.0	3.5±0.0
C18:1n9	170.0±14.9 <sup>a</sup>	185.7±0.1 <sup>a</sup>	142.7±0.1 <sup>b</sup>	179.6±0.6 <sup>a</sup>	177.9±1.2 <sup>a</sup>	170.3±1.7 <sup>a</sup>	185.9±0.1 <sup>a</sup>	151.1±0.3 <sup>b</sup>	176.9±0.3 <sup>a</sup>	183.9±0.1 <sup>a</sup>	185.0±0.1 <sup>a</sup>
C18:2n6	576.0±0.5 <sup>c</sup>	575.1±0.1 <sup>c</sup>	614.8±0.7 <sup>a</sup>	580.4±0.3 <sup>c</sup>	580.1±9.6 <sup>c</sup>	577.4±2.9 <sup>c</sup>	574.0±0.2 <sup>c</sup>	597.4±3.8 <sup>b</sup>	582.9±0.5 <sup>c</sup>	577.8±0.1 <sup>c</sup>	576.8±1.1 <sup>c</sup>
C18:3n3	1.0±0.1	1.0±0.0	1.2±0.1	1.1±0.1	1.1±0.0	1.0±0.0	1.2±0.1	1.3±0.1	1.1±0.0	1.1±0.0	1.1±0.1
TSFAs	233.3±0.5 <sup>bc</sup>	233.3±0.5 <sup>bc</sup>	236.5±0.3 <sup>b</sup>	232.6±0.2 <sup>cd</sup>	229.0±2.2 <sup>d</sup>	231.2±0.9 <sup>cd</sup>	233.5±0.5 <sup>bc</sup>	241.9±3.2 <sup>a</sup>	233.7±0.2 <sup>bc</sup>	232.7±0.1 <sup>bcd</sup>	233.0±0.5 <sup>bc</sup>
TMUFAs	170.0±14.9 <sup>a</sup>	185.7±0.1 <sup>a</sup>	142.7±0.1 <sup>b</sup>	179.6±0.6 <sup>a</sup>	177.9±8.7 <sup>a</sup>	170.3±1.7 <sup>a</sup>	185.9±0.7 <sup>a</sup>	151.1±0.3 <sup>b</sup>	176.9±0.3 <sup>a</sup>	183.9±0.1 <sup>a</sup>	185.0±0.1 <sup>a</sup>
TPUFAs	577.0±0.5 <sup>c</sup>	576.2±0.1 <sup>c</sup>	616.0±0.5 <sup>a</sup>	581.4±0.4 <sup>c</sup>	581.2±9.6 <sup>c</sup>	578.4±2.9 <sup>c</sup>	575.2±0.3 <sup>c</sup>	598.7±3.7 <sup>b</sup>	584.1±0.6 <sup>c</sup>	578.9±0.1 <sup>c</sup>	577.9±1.2 <sup>c</sup>

Different letters within the same line indicate significant differences among cooking process ( $P < 0.05$ ). : Palmitic acid, C18:0:Stearic acid, C20:0: Arachic acid; C18:1n9: Oleic aci; C18:2n6: Linoléic acid; C18:3n3: Linoléic acid; TSFA = Total Saturated fatty acids; TMUFA = Total Monounsaturated fatty acids; TPUFA = Total Polyunsaturated fatty acids

TABLE 3. Peroxide and acid values of *Lagenaria siceraria* oil extracted by hot-water flotation during seeds processing

Parameters	Untreated seeds (control)	Cooking process						Codex norm for cold pressed and virgin oils			
		Roasting at 100 °C during 25 min			Roasting at 125 °C during 25 min						
		0	10	35	60	90	0		10	35	60
PV (meq O <sub>2</sub> kg <sup>-1</sup> oil)	nd	1.3±0.0 <sup>f</sup>	1.7±0.0 <sup>d</sup>	1.9±0.0 <sup>c</sup>	2.9±0.0 <sup>a</sup>	nd	nd	1.1±0.0 <sup>g</sup>	2.3±0.0 <sup>b</sup>	1.7±0.0 <sup>e</sup>	< 15 meq O <sub>2</sub> kg <sup>-1</sup>
AI (g KOH kg <sup>-1</sup> oil)	nd	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	nd	nd	0.2±0.0	0.2±0.0	0.2±0.0	< 4 g KOH kg <sup>-1</sup>

Different letters within the same line indicate significant differences among cooking process ( $P < 0.05$ ). PV = Peroxide Index, AI = acid index, nd = not determined because no recovered oils

palmitic acid (147.1 to 160.6 g kg<sup>-1</sup>). They also showed that roasting and boiling had no significant effect on oils recovered after hot-water flotation.

**Extraction methods.** Table 5 shows peroxide and acid index values of *Lagenaria siceraria* oil extracted with solvent and recovered after hot-water flotation. The results showed significant different ( $P < 0.05$ ) between peroxide values of the both extraction methods during cooking while there are no significant difference for acid index values. The highest values of peroxides values were observed in oils extracted with the solvent (2.26 to 4.49 meq O<sub>2</sub> kg<sup>-1</sup> oil), and the lowest in oils extracted by hot-water flotation (1.14 to 2.94 meq O<sub>2</sub> kg<sup>-1</sup> oil).

Fatty acids composition of oil extracted following two different methods is presented in Table 6. Palmitic (147.1 to 162.1 g kg<sup>-1</sup>) and stearic acids (70.2 to 80.1 g kg<sup>-1</sup>) were the most representative saturated fatty acids (SFAs) in *Lagenaria siceraria* oil; while arachidic acids (1.0 to 1.4 g kg<sup>-1</sup>) were present in low concentrations for all extracts used. *Lagenaria siceraria* oil contains mainly unsaturated fatty acids (UFAs) in both oils extracted with solvent and recovered after hot-water flotation. Oleic (142.7 to 185.7 g kg<sup>-1</sup>) and linoleic acids (567.0 to 614.8 g kg<sup>-1</sup>) were the major UFAs in all *L. siceraria* oil samples obtained by the two extraction methods.

The fatty acids content following extraction method in different cooking process was significantly different ( $P < 0.05$ ) in some cases. Indeed, for SFAs, the differences were observed when seeds were roasted at 100 °C and boiled during 10, 60 and 90 min; and roasted at 125 °C and boiled during 35 and 90 min. For MUFAs, the differences were revealed when seeds were roasted at 100 °C and boiled during 10 min; and roasted at 125 °C and boiled during 10, 35 and 90 min. The highest SFAs and MUFAs contents were obtained in recovered oils after hot-water flotation process. For PUFA, the differences were observed when seeds were roasted at 100 °C

TABLE 4. Fatty acids composition of *Lagenaria siceraria* oil extracted by hot-water flotation during seeds processing

Fatty acid (g kg <sup>-1</sup> )	Untreated seeds (control)	Cooking process									
		Roasting at 100 °C during 25 min					Roasting at 125 °C during 25 min				
		Boiling times (min)					Boiling times (min)				
		0	10	35	60	90	0	10	35	60	90
C16:0	nd	nd	159.5±0.7 <sup>a</sup>	156.4±.1 <sup>a</sup>	161.3±2.0 <sup>a</sup>	158.9±0.7 <sup>a</sup>	nd	160.6±2.2 <sup>a</sup>	159.0±1.4 <sup>a</sup>	147.1±20.4 <sup>a</sup>	159.5±0.5 <sup>a</sup>
C18:0	nd	nd	79.6±0.0 <sup>a</sup>	79.6±0.3 <sup>a</sup>	78.8±0.0 <sup>a</sup>	78.8±0.9 <sup>a</sup>	nd	80.0±0.1 <sup>a</sup>	80.1±0.5 <sup>a</sup>	73.8±7.9 <sup>a</sup>	79.1±0.1 <sup>a</sup>
C20:0	nd	nd	3.9±0.2 <sup>a</sup>	3.9±0.0 <sup>a</sup>	3.8±0.0 <sup>a</sup>	3.9±0.2 <sup>a</sup>	nd	3.8±0.0 <sup>a</sup>	3.9±0.1 <sup>a</sup>	3.7±0.4 <sup>a</sup>	4.0±0.2 <sup>a</sup>
C18:1n9	nd	nd	182.2±0.3 <sup>a</sup>	180.0±0.5 <sup>a</sup>	179.0±0.4 <sup>a</sup>	174.5±0.8 <sup>a</sup>	nd	181.0±0.1 <sup>a</sup>	184.6±0.5 <sup>b</sup>	166.2±21.5 <sup>a</sup>	175.6±0.2 <sup>b</sup>
C18:2n6	nd	nd	568.1±0.4 <sup>b</sup>	569.8±0.1 <sup>b</sup>	571.4±2.2 <sup>a</sup>	570.8±4.6 <sup>a</sup>	nd	567.9±1.0 <sup>b</sup>	567.0±.5 <sup>b</sup>	600.5±44.6 <sup>a</sup>	574.8±0.4 <sup>b</sup>
C18:3n3	nd	nd	1.4±0.1 <sup>a</sup>	1.4±0.1 <sup>a</sup>	1.4±0.0 <sup>a</sup>	1.4±0.0 <sup>a</sup>	nd	1.3±0.2 <sup>a</sup>	1.3±0.1 <sup>a</sup>	1.2±0.2 <sup>a</sup>	1.4±0.1 <sup>a</sup>
TSFAs	nd	nd	242.9±0.8 <sup>a</sup>	239.8±5.8 <sup>a</sup>	244.0±2.0 <sup>a</sup>	241.7±0.4 <sup>a</sup>	nd	244.4±2.1 <sup>a</sup>	243.0±1.7 <sup>a</sup>	224.5±27.9 <sup>a</sup>	242.6±0.4 <sup>a</sup>
TMUFAs	nd	nd	182.2±0.3 <sup>a</sup>	180.0±0.5 <sup>a</sup>	179.0±0.4 <sup>a</sup>	174.5±0.8 <sup>a</sup>	nd	181.0±0.1 <sup>a</sup>	184.6±0.5 <sup>a</sup>	166.2±21.5	175.6±0.2 <sup>b</sup>
TPUFAs	nd	nd	569.4±0.3 <sup>b</sup>	571.1±0.0 <sup>b</sup>	572.8±2.1 <sup>a</sup>	572.1±4.6 <sup>a</sup>	nd	569.1±1.2 <sup>b</sup>	568.3±0.6 <sup>b</sup>	601.6±44.8 <sup>a</sup>	576.1±0.2 <sup>a</sup>

Different letters within the same line indicate significant differences among cooking process (P <0.05). C16:0: Palmitic acid, C18:0:Stearic acid, C20:0: Arachic acid; C18:1n9: Oleic aci; C18:2n6: Linoléic acid; C18:3n3: Linoléic acid; TSFA = Total Saturated fatty acids; TMUFA = Total Monounsaturated fatty acids; TPUFA = Total Polyunsaturated fatty acids

TABLE 5. Changes in peroxide and acid values of *Lagenaria siceraria* oil extracted with solvent and by hot-water flotation

Oil index	Extraction methods	Untreated seeds (control)	Cooking process											
			Roasting at 100 °C during 25 min						Roasting at 125 °C during 25 min					
			Boiling times (min)		Boiling times (min)		Boiling times (min)		Boiling times (min)		Boiling times (min)		Boiling times (min)	
		0	10	35	60	90	0	10	35	60	90			
PV (meq O <sub>2</sub> kg <sup>-1</sup> oil)	Solvent	3.8±0.0	3.3±0.1	4.5±0.1 <sup>a</sup>	4.1±1.0 <sup>a</sup>	3.8±0.0 <sup>a</sup>	3.1±0.1 <sup>a</sup>	2.3±0.1	4.1±0.1	3.2±0.0 <sup>a</sup>	3.1±0.10 <sup>a</sup>	3.5±0.2 <sup>a</sup>		
	Hot-water flotation	nd	nd	1.3±0.0 <sup>b</sup>	1.7±0.0 <sup>b</sup>	1.9±0.0 <sup>b</sup>	2.9±0.0 <sup>b</sup>	nd	nd	1.1±0.0 <sup>b</sup>	2.3±0.0 <sup>b</sup>	1.7±0.0 <sup>b</sup>		
AI (g KOH kg <sup>-1</sup> oil)	Solvent	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0		
	Hot-water flotation	nd	nd	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	n	nd	0.2±0.0	0.2±0.0	0.2±0.0		

In column for each parameter, means with the same superscript do not differ significantly ( $P > 0.05$ ). PV: = Peroxide Index, AI = acid index; Nd = not determined

and boiled during 10, 35 and 90 min; and roasted at 125 °C and boiled during 35 and 90 min. The highest PUFAs contents were obtained in oils extracted with solvent (574.0 to 614.8 g kg<sup>-1</sup>) and the lowest in oils extracted by hot-water flotation (567.0 to 600.2 g kg<sup>-1</sup>).

## DISCUSSION

In this study peroxide values increase with extended boiling duration (10 min for oils extracted with solvent and 90 min for roasting at 100 °C and 60 min for roasting at 125 °C for oils extracted by hot-water flotation) and decrease thereafter. The increase of peroxide value to reach the maximum and decrease could be due to the fact that the peroxides are labile intermediate compounds which decompose into several secondary oxidation products such as aldehydes, ketones and esters. This result is in concordance to that of Abramovic *et al.* (2005) studies who also showed that during oxidation, the peroxide value may reach a maximum and then decreases. The reduction in the peroxide values occurred earlier for oil extracted with the solvent and later for the oil recovered after ebullition. This means that oil extracted with the solvent deteriorates faster than that recovered after hot-water flotation. Nevertheless, during cooking both studied oils had peroxide values below limit of CODEX-STAN 210 (1999) which is inferior to 15 milliequivalents of active oxygen per kg for virgin oils and inferior to 10 milliequivalents active oxygen per kg for cooking oil (O'Brien, 2009). In general, the lower the peroxide value, the better the quality of the oil is. *Lagenaria siceraria* seeds are consumed as a thickener soup in Côte d'Ivoire and in Nigeria. These seeds are cooked before eating. It is generally known that fats and oils can be deteriorated under heat. The assessment of peroxide and acid index values could indicate if sauce made from this cooked seeds or the oils present in this sauce are suitable for consumption whatever the cooking process. Peroxide value is used only in the case of oil that is not rancid (Popa *et al.*, 2017). It is applicable for

TABLE 6. Changes in fatty acids composition of *Lagenaria siceraria* oil extracted with solvent and by hot-water flotation

Fatty acid (g.kg <sup>-1</sup> )	Extraction methods	Untreated seeds (control)	Cooking process									
			Roasting at 100 °C during 25 min					Roasting at 125 °C during 25 min				
			Boiling times (min)									
			0	10	35	60	90	0	10	35	60	90
Palmitic (C16:0)	Solvent	153.4 ± 0.4	154.3 ± 0.5	158.4 ± 0.5 <sup>a</sup>	152.9 ± 0.1 <sup>a</sup>	155.0 ± 1.9 <sup>a</sup>	153.8 ± 0.2 <sup>b</sup>	155.2 ± 1.0	162.1 ± 3.5 <sup>a</sup>	154.5 ± 0.2 <sup>b</sup>	154.5 ± 0.6 <sup>a</sup>	155.0 ± 0.8 <sup>b</sup>
	Hot-water flotation	nd	nd	159.5 ± 0.7 <sup>a</sup>	156.4 ± 6.1 <sup>a</sup>	161.3 ± 2.0 <sup>a</sup>	158.9 ± 0.7 <sup>a</sup>	nd	160.6 ± 2.2 <sup>a</sup>	159.0 ± 1.4 <sup>a</sup>	147.1 ± 20.4 <sup>a</sup>	159.5 ± 0.5 <sup>a</sup>
Stearic (C18:0)	Solvent	76.4 ± 1.0	75.2 ± 0.2	74.7 ± 0.2 <sup>b</sup>	76.1 ± 0.0 <sup>b</sup>	70.2 ± 4.3 <sup>a</sup>	73.6 ± 0.3 <sup>b</sup>	74.8 ± 0.5	76.3 ± 0.2 <sup>b</sup>	75.6 ± 0.0 <sup>b</sup>	74.8 ± 0.5 <sup>a</sup>	74.6 ± 0.3 <sup>b</sup>
	Hot-water flotation	nd	nd	79.6 ± 0.0 <sup>a</sup>	79.6 ± 0.3 <sup>a</sup>	78.8 ± 0.0 <sup>a</sup>	78.8 ± 0.9 <sup>a</sup>	nd	80.0 ± 0.1 <sup>a</sup>	80.1 ± 0.5 <sup>a</sup>	73.8 ± 7.9 <sup>a</sup>	79.1 ± 0.1 <sup>a</sup>
Arachidic (C20:0)	Solvent	3.5 ± 0.1	3.5 ± 0.1	3.3 ± 0.0 <sup>b</sup>	3.5 ± 0.1 <sup>a</sup>	3.8 ± 0.2 <sup>a</sup>	3.8 ± 0.3 <sup>a</sup>	3.5 ± 0.0	3.4 ± 0.0 <sup>b</sup>	3.6 ± 0.0 <sup>a</sup>	3.4 ± 0.0 <sup>a</sup>	3.5 ± 0.0 <sup>a</sup>
	Hot-water flotation	nd	nd	3.9 ± 0.2 <sup>a</sup>	3.9 ± 0.0 <sup>a</sup>	3.8 ± 0.0 <sup>a</sup>	3.9 ± 0.2 <sup>a</sup>	nd	3.8 ± 0.0 <sup>a</sup>	3.9 ± 0.1 <sup>a</sup>	3.7 ± 0.4 <sup>a</sup>	4.0 ± 0.2 <sup>a</sup>
Oleic (C18:1n9)	Solvent	170.0 ± 2.1	185.7 ± 0.1	142.7 ± 0.1 <sup>b</sup>	179.6 ± 0.6 <sup>a</sup>	177.9 ± 1.2 <sup>a</sup>	170.3 ± 1.7 <sup>a</sup>	185.9 ± 0.1	151.1 ± 0.3 <sup>b</sup>	176.9 ± 0.3 <sup>a</sup>	183.9 ± 0.1 <sup>a</sup>	185.0 ± 0.1 <sup>a</sup>
	Hot-water flotation	nd	nd	182.2 ± 0.3 <sup>a</sup>	180.0 ± 0.5 <sup>a</sup>	179.0 ± 0.4 <sup>a</sup>	174.5 ± 0.8 <sup>a</sup>	nd	181.0 ± 0.1 <sup>a</sup>	184.6 ± 0.5 <sup>b</sup>	166.2 ± 21.5 <sup>a</sup>	175.6 ± 2.2 <sup>b</sup>
Linoléic (C18:2n6)	Solvent	576.0 ± 0.5	575.1 ± 0.1	614.8 ± 0.7 <sup>a</sup>	580.4 ± 0.3 <sup>a</sup>	580.1 ± 9.6 <sup>a</sup>	577.4 ± 2.9 <sup>a</sup>	574.0 ± 0.2	597.4 ± 3.8 <sup>a</sup>	582.9 ± 0.5 <sup>a</sup>	577.8 ± 0.1 <sup>a</sup>	576.8 ± 1.1 <sup>a</sup>
	Hot-water flotation	nd	nd	568.1 ± 0.4 <sup>b</sup>	569.8 ± 0.1 <sup>b</sup>	571.4 ± 2.2 <sup>a</sup>	570.8 ± 4.6 <sup>a</sup>	nd	567.9 ± 1.0 <sup>b</sup>	567.0 ± 0.5 <sup>b</sup>	600.5 ± 44.6 <sup>a</sup>	574.8 ± 0.4 <sup>b</sup>
Linoléic (C18:3n3)	Solvent	1.0 ± 0.1	1.0 ± 0.0	1.2 ± 0.1 <sup>a</sup>	1.1 ± 0.1 <sup>a</sup>	1.1 ± 0.0 <sup>a</sup>	1.0 ± 0.0 <sup>a</sup>	1.2 ± 0.1	1.3 ± 0.1 <sup>a</sup>	1.1 ± 0.0 <sup>b</sup>	1.1 ± 0.0 <sup>b</sup>	1.1 ± 0.1 <sup>a</sup>
	Hot-water flotation	nd	nd	1.4 ± 0.1 <sup>a</sup>	1.4 ± 0.1 <sup>a</sup>	1.4 ± 0.0 <sup>a</sup>	1.4 ± 0.0 <sup>a</sup>	nd	1.3 ± 0.2 <sup>a</sup>	1.3 ± 0.1 <sup>a</sup>	1.2 ± 0.2 <sup>a</sup>	1.4 ± 0.1 <sup>a</sup>
TSFAs	Solvent	233.3 ± 0.5	233.3 ± 0.5	236.5 ± 0.3 <sup>b</sup>	232.6 ± 0.2 <sup>a</sup>	229.0 ± 2.2 <sup>b</sup>	231.2 ± 0.9 <sup>b</sup>	233.5 ± 0.5	241.9 ± 3.2 <sup>a</sup>	233.7 ± 0.2 <sup>b</sup>	232.7 ± 0.1 <sup>a</sup>	233.0 ± 0.5 <sup>b</sup>
	Hot-water flotation	nd	nd	242.9 ± 0.8 <sup>a</sup>	239.8 ± 5.8 <sup>a</sup>	244.0 ± 2.0 <sup>a</sup>	241.7 ± 0.4 <sup>a</sup>	nd	244.4 ± 2.1 <sup>a</sup>	243.0 ± 1.7 <sup>a</sup>	224.5 ± 27.9 <sup>a</sup>	242.6 ± 0.4 <sup>a</sup>
TMUFA	Solvent	170.0 ± 2.1	185.7 ± 0.1	142.7 ± 0.1 <sup>b</sup>	179.6 ± 0.6 <sup>a</sup>	177.9 ± 8.7 <sup>a</sup>	170.3 ± 1.7 <sup>a</sup>	185.9 ± 0.7	151.1 ± 0.3 <sup>b</sup>	176.9 ± 0.3 <sup>b</sup>	183.9 ± 0.1 <sup>a</sup>	185.0 ± 0.1 <sup>a</sup>
	Hot-water flotation	nd	nd	182.2 ± 0.3 <sup>a</sup>	180.0 ± 0.5 <sup>a</sup>	179.0 ± 0.4 <sup>a</sup>	174.5 ± 0.8 <sup>a</sup>	nd	181.0 ± 0.1 <sup>a</sup>	184.6 ± 0.5 <sup>a</sup>	166.2 ± 21.5 <sup>a</sup>	175.6 ± 0.2 <sup>b</sup>
TPUFA	Solvent	577.0 ± 0.5	576.2 ± 0.1	616.0 ± 0.5 <sup>a</sup>	581.4 ± 0.4 <sup>a</sup>	581.2 ± 9.6 <sup>a</sup>	578.4 ± 2.9 <sup>a</sup>	575.2 ± 0.3	598.7 ± 3.7 <sup>a</sup>	584.1 ± 0.6 <sup>a</sup>	578.9 ± 0.1 <sup>a</sup>	577.9 ± 1.2 <sup>a</sup>
	Hot-water flotation	nd	nd	569.4 ± 0.3 <sup>b</sup>	571.1 ± 0.0 <sup>b</sup>	572.8 ± 2.1 <sup>a</sup>	572.1 ± 4.6 <sup>a</sup>	nd	569.1 ± 1.2 <sup>b</sup>	568.3 ± 0.6 <sup>b</sup>	601.6 ± 44.8 <sup>a</sup>	576.1 ± 0.2 <sup>a</sup>

In column for each parameter, means with the same superscript do not differ significantly ( $P > 0.05$ ; Nd = not determined; C16:0: Palmitic acid; C18:0: Stearic acid; C20:0: Arachic acid C18:1n9: Oleic acid; C18:2n6: Linoléic acid; C18:3n3: Linoléic acid; TSFAs = Total saturated fatty acids; TMUFA = Total monounsaturated fatty acids; TPUFA = Total polyunsaturated fatty acids

monitoring the formation of peroxides in the early stages of oxidation.

In this study, Acid index values were below 0.6 mg KOH g<sup>-1</sup> which is the permissible limit of Acid index value for all edible oils according to FAO/WHO recommendation (AOCS, 2003). Acid index determination is often used as a general indication of the condition and edibility of oil.

Results showed no change in *Lagenaria siceraria* oils fatty acids composition recovered after hot-water flotation process. This is great because it has been established that food-processing techniques can affect fatty acid composition of oils when hardly subjected to successive heating (Lee *et al.*, 2004). These results agreed with those of Mariod *et al.* (2012), who reported that safflower oil from seeds roasted at 180 °C, during different times and boiled was not different from oil of untreated (raw) safflower seeds. On the other hand, the results indicated a variation in fatty acids content of the oils extracted with solvent after 10 min of boiling. The variation observed may be due to lipolytic activity, interactions between lipids and other constituents or processing conditions generate by the use of solvent. The fatty acid composition of oil is an indicator of its stability (Jung-Mi and Jeonghee, 2012). The high content of polyunsaturated fatty acids makes *L. siceraria* seed oil very unstable (Loukou *et al.*, 2013), which expose it to polymerisation, oxidation and hydrolysis (Goswami *et al.*, 2015).

Peroxide values were influenced by the extraction methods and the highest values were observed in oil extracted with the solvent. The higher peroxide obtained in oil extracted with solvent suggests high primary oxidation of oil during Soxhlet extraction (Jessinta *et al.*, 2014). However, these peroxides values were less than 10 meq O<sub>2</sub> kg<sup>-1</sup> oil, value, which characterises most conventional oils. Indeed, in previous studies, Yong *et al.* (2006) showed that the lower peroxide values (10 meq O<sub>2</sub> kg<sup>-1</sup> oil) indicated an acceptable level of oxidation phenomenon.

The resulting oil from the two extraction methods have shown the highest SFAs and MUFAs contents in recovered oil after ebullition; and the highest PUFAs contents in oils extracted with the solvent. The Soxhlet method provided the highest PUFA, mainly due to the high operational temperature, solvent recycle and solvent/solute interactions (Abdolshahi *et al.*, 2015). Oils obtained by hot-water flotation extraction showed the lowest PUFA values, despite the highest concentrations of SFAs and MUFAs. This is because oil samples were not chemically esterified before fatty acid analysis (Mezzomo *et al.*, 2010). Natural esterification may occur during sample handling, allowing solvent polarity to influence oil fractionation. This can be explained by the use of high temperature and reflux in Soxhlet extraction overcoming the polarity effect during the extraction of PUFAs. Thus, in order to obtain *L. siceraria* oil with high quality, attention must be paid to the technique to oil extraction because some of them can be an agent of deterioration.

## CONCLUSION

This study has showed that the oils present in roasted seeds and the sauce (roasted and boiled seeds) made from *L. siceraria* seeds are suitable for consumption. The oils present low values of quality index which meets FAO/WHO recommendation and their fatty acids composition does not change, although there are potential sources of polyunsaturated fatty acids. For oil production, use of hot-water flotation process is recommended because use of solvent for extracting *L. siceraria* oil makes it very unstable with high peroxide values and variation of fatty acids content.

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