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 meqO2 kg−1 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. 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 méqO2.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 Sabir (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 egusi 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 Achetu (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 distillated 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 (BF3) and methanol (140 mg ml⁻¹), 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
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The 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 O₂ kg⁻¹ oil) and 125 °C (4.12 meq O₂ kg⁻¹ 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 g kg⁻¹), oleic acid (142.7 to 185.9 g kg⁻¹), and palmitic acid (153.4 to 162.1 g kg⁻¹) (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 increased 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⁻¹) 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 O₂ kg⁻¹ oil) and 60 min for seeds roasted at 125 °C (2.31 meq O₂ kg⁻¹ oil). The results have showed that the major fatty acids in *L. siceraria* oils were linoleic acid (568.1 to 600.5 g kg⁻¹), oleic acid (166.2 to 182.2 g kg⁻¹), and palmitic acid (67.4 to 78.9 g kg⁻¹).

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

| Parameters | Untreated seeds (control) | Roasting at 100 °C during 25 min | Roasting at 125 °C during 25 min | Codex norm for cold pressed and virgin oils |
|------------|---------------------------|----------------------------------|----------------------------------|-------------------------------------------|
| Boiling times (min) | 0 | 10 | 35 | 60 | 90 | 0 | 10 | 35 | 60 | 90 |
| PV (meq O₂ kg⁻¹ oil) | 3.8±0.0abcd | 3.3±0.1c | 4.5±0.1ab | 4.1±1.0b | 3.8±0.0bc | 4.5±0.1ab | 3.1±0.1a | 3.2±0.0bc | 3.1±0.1a | 3.5±0.2bc | <15 meq O₂ kg⁻¹ oil |
| AI (g KOH kg⁻¹ 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 | <4 g KOH kg⁻¹ oil |

Different letters within the same line indicate significant differences among cooking process (P <0.05). PV = Peroxide Index, AI = acid index.
| Fatty acid (g kg\(^{-1}\)) | Untreated seeds (control) | Cooking process | Boiling times (min) | Boiling times (min) |
|-----------------------------|---------------------------|----------------|-------------------|-------------------|
|                             | Roasting at 100 °C during 25 min | Roasting at 125 °C during 25 min |
|                             | 0  | 10 | 35 | 60 | 90 | 0  | 10 | 35 | 60 | 90 |
| C16:0                       | 153.4±0.4\(^{c}\) | 154.3±0.5\(^{c}\) | 158.4±0.5\(^{c}\) | 152.9±0.1\(^{c}\) | 155.0±1.9\(^{c}\) | 153.8±0.2\(^{c}\) | 155.2±1.0\(^{c}\) | 162.1±3.5\(^{c}\) | 154.5±0.2\(^{c}\) | 154.5±0.6\(^{c}\) | 155.0±0.8\(^{c}\) |
| 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\(^{a}\) | 185.7±0.1\(^{a}\) | 142.7±0.1\(^{a}\) | 179.6±0.6\(^{a}\) | 177.9±1.2\(^{a}\) | 170.3±1.7\(^{a}\) | 185.9±0.1\(^{a}\) | 151.1±0.3\(^{a}\) | 176.9±0.3\(^{a}\) | 183.9±0.1\(^{a}\) | 185.0±0.1\(^{a}\) |
| C18:2n6                     | 576.0±0.5\(^{c}\) | 575.1±0.1\(^{c}\) | 614.8±0.7\(^{c}\) | 580.4±0.3\(^{c}\) | 580.1±9.6\(^{c}\) | 577.4±2.9\(^{c}\) | 574.0±0.2\(^{c}\) | 597.4±3.8\(^{c}\) | 582.9±0.5\(^{c}\) | 577.8±0.1\(^{c}\) | 576.8±1.1\(^{c}\) |
| 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\(^{c}\) | 233.3±0.5\(^{c}\) | 236.5±0.3\(^{c}\) | 232.6±0.2\(^{c}\) | 229.0±2.2\(^{c}\) | 231.2±0.9\(^{c}\) | 233.5±0.5\(^{c}\) | 241.9±3.2\(^{c}\) | 233.7±0.2\(^{c}\) | 232.7±0.1\(^{c}\) | 233.0±0.5\(^{c}\) |
| TMUFAs                      | 170.0±14.9\(^{a}\) | 185.7±0.1\(^{a}\) | 142.7±0.1\(^{a}\) | 179.6±0.6\(^{a}\) | 177.9±8.7\(^{a}\) | 170.3±1.7\(^{a}\) | 185.9±0.1\(^{a}\) | 151.1±0.3\(^{a}\) | 176.9±0.3\(^{a}\) | 183.9±0.1\(^{a}\) | 185.0±0.1\(^{a}\) |
| TPUFAs                      | 577.0±0.5\(^{c}\) | 576.2±0.1\(^{c}\) | 616.0±0.5\(^{c}\) | 581.4±0.4\(^{c}\) | 581.2±9.6\(^{c}\) | 578.4±2.9\(^{c}\) | 575.2±0.3\(^{c}\) | 597.2±3.7\(^{c}\) | 584.1±0.6\(^{c}\) | 578.9±0.1\(^{c}\) | 577.9±1.2\(^{c}\) |

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 acid; C18:2n6: Linoléic acid; C18:3n3: Linolénic 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 |                                             |
|                          | Boiling times (min)       | Boiling times (min) |                                             |
|                          | 0                        | 10              | 35            | 60            | 90            | 0     | 10    | 35    | 60        | 90        | <15 meq O₂ kg⁻¹ oil |
| PV (meq O₂ kg⁻¹ oil)     | nd                       | 1.3±0.0         | 1.7±0.0       | 1.9±0.0       | 2.9±0.0       | nd    | 1.1±0.0 | 2.3±0.0 | 1.7±0.0    | <15 meq O₂ kg⁻¹ oil |
| Al (g KOH kg⁻¹ oil)      | nd                       | 0.2±0.0         | 0.2±0.0       | 0.2±0.0       | 0.2±0.0       | nd    | 0.2±0.0 | 0.2±0.0 | 0.2±0.0    | <4 g KOH kg⁻¹ oil  |

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

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 O₂ kg⁻¹ oil), and the lowest in oils extracted by hot-water flotation (0.2 to 2.94 meq O₂ kg⁻¹ oil).

Fatty acids composition of oil extracted following two different methods is presented in Table 6. Palmitic (147.1 to 162.1 g kg⁻¹) and stearic acids (70.2 to 80.1 g kg⁻¹) were the most representative saturated fatty acids (SFAs) in *Lagenaria siceraria* oil; while arachidic acids (1.0 to 1.4 g kg⁻¹) were present in low concentrations for all extracts used. *Lagenaria siceraria* oil contains mainly unsaturated fatty acids (UFAs), especially oleic (142.7 to 185.7 g kg⁻¹) and linoleic acids (567.0 to 614.8 g kg⁻¹) were the major UFAs in both extracts of *Lagenaria siceraria* oil. 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 35 min; and roasted at 125 °C and boiled during 10 min; and roasted at 125 °C during 10, 60 and 90 min; and roasted at 125 °C and boiled during 10, 60 and 90 min. The highest SFAs and MUFA contents were observed in recovered oils after hot-water flotation process. For PUFA, the differences were also observed when seeds were roasted at 100 °C and boiled during 35 and 90 min. The highest SFAs and MUFA contents were observed in recovered oils after hot-water flotation process.
| Fatty acid (g kg\(^{-1}\)) | Untreated seeds (control) | Cooking process | 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  | nd | 159.5±0.7\(^a\) | 156.4±1.\(^a\) | 161.3±2.0\(^a\) | 158.9±0.7\(^a\) | nd  | 160.6±2.2\(^a\) | 159.0±1.4\(^a\) | 147.1±20.4\(^a\) | 159.5±0.5\(^a\) |
| C18:0                  | nd                       | nd  | nd | 79.6±0.0\(^b\)  | 79.6±0.3\(^a\)  | 78.8±0.0\(^a\)  | 78.8±0.9\(^a\)  | nd  | 80.0±0.1\(^a\)  | 80.1±0.5\(^a\)  | 73.8±7.9\(^a\)  | 79.1±0.1\(^a\)  |
| C20:0                  | nd                       | nd  | nd | 3.9±0.2\(^a\)   | 3.9±0.0\(^a\)   | 3.8±0.0\(^a\)   | 3.9±0.2\(^a\)   | nd  | 3.8±0.0\(^a\)   | 3.9±0.1\(^a\)   | 3.7±0.4\(^a\)   | 4.0±0.2\(^a\)   |
| C18:1n9                | nd                       | nd  | nd | 182.2±0.3\(^b\) | 180.0±0.5\(^a\) | 179.0±0.4\(^a\) | 174.5±0.8\(^a\) | nd  | 181.0±0.1\(^a\) | 184.6±0.5\(^a\) | 166.2±21.5\(^a\) | 175.6±0.2\(^b\) |
| C18:2n6                | nd                       | nd  | nd | 568.1±0.4\(^b\) | 569.8±0.1\(^a\) | 571.4±2.2\(^a\) | 570.8±4.6\(^a\) | nd  | 567.9±1.0\(^b\) | 567.0±5.0\(^b\) | 600.5±44.6\(^b\) | 574.8±4.0\(^b\) |
| C18:3n3                | nd                       | nd  | nd | 1.4±0.1\(^a\)   | 1.4±0.1\(^a\)   | 1.4±0.0\(^a\)   | 1.4±0.0\(^a\)   | nd  | 1.3±0.2\(^a\)   | 1.3±0.1\(^a\)   | 1.2±0.2\(^a\)   | 1.4±0.1\(^a\)   |
| TSFAs                   | nd                       | nd  | nd | 242.9±0.8\(^a\) | 239.8±5.8\(^a\) | 244.0±2.0\(^a\) | 241.7±0.4\(^a\) | nd  | 244.4±2.1\(^a\) | 243.0±1.7\(^a\) | 224.5±27.9\(^a\) | 242.6±0.4\(^a\) |
| TPUFAs                  | nd                       | nd  | nd | 182.2±0.3\(^a\) | 180.0±0.5\(^a\) | 179.0±0.4\(^a\) | 174.5±0.8\(^a\) | nd  | 181.0±0.1\(^a\) | 184.6±0.5\(^a\) | 166.2±21.5\(^a\) | 175.6±0.2\(^b\) |
| TSFAs                   | nd                       | nd  | nd | 569.4±0.3\(^b\) | 571.1±0.0\(^a\) | 572.8±2.1\(^a\) | 572.1±4.6\(^a\) | nd  | 569.1±1.2\(^b\) | 568.3±0.6\(^b\) | 601.6±44.8\(^b\) | 576.1±0.2\(^b\) |

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 acid; C18:2n6: Linoléic acid; C18:3n3: Linolénic 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) |
|           |                    |                           | 0    | 10    | 35    | 60    | 90    | 0    | 10    | 35    | 60    | 90    |
| PV (meq O$_2$ kg$^{-1}$ oil) | Solvent | 3.8±0.0 | 3.3±0.1 | 4.5±0.1$^a$ | 4.1±1.0$^a$ | 3.8±0.0$^a$ | 3.1±0.1$^a$ | 2.3±0.1 | 4.1±0.1 | 3.2±0.0$^a$ | 3.1±0.0$^a$ | 3.5±0.2$^a$ |
|           | Hot-water flotation | nd                        | nd                          | 1.3±0.0$^b$ | 1.7±0.0$^b$ | 1.9±0.0$^b$ | 2.9±0.0$^b$ | nd        | nd                          | 1.1±0.0$^b$ | 2.3±0.0$^b$ | 1.7±0.0$^b$ |
| AI (g KOH kg$^{-1}$ 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 | 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 | 0.2±0.0 | 0.2±0.0 | 0.2±0.0 | 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.
| Fatty acid (g.kg\(^{-1}\)) | Extraction methods | Untreated seeds (control) | Cooking process |
|-----------------------------|--------------------|---------------------------|----------------|
|                             |                    | Roasting at 100 °C during 25 min | Cooking process |
|                             |                    | Boiling times (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\(^a\) | 152.9 ± 0.1\(^b\) | 155.0 ± 1.1\(^b\) | 153.8 ± 0.2\(^b\) | 155.2 ± 1.0 | 162.1 ± 3.5\(^b\) | 154.5 ± 0.2\(^b\) | 154.5 ± 0.6 | 155.0±0.3\(^a\) |
| Hot-water flotation | nd | 159.5±0.7\(^a\) | 156.4±1.1\(^b\) | 161.3±2.0\(^b\) | 159.9±0.7\(^b\) | 74.8±0.5 | 76.3±0.2\(^b\) | 75.6±0.0 | 74.8±0.5 \(^b\) | 74.6±0.3\(^b\) |
| Stearic (C18:0) | Solvent | 76.4± 1.0 | 75.2± 0.2 | 74.7± 0.2 | 76.1±0.0 | 70.2±4.3 | 73.6±0.3 | 3.5±0.0 | 3.4±0.0 | 3.4±0.0 | 3.5±0.0 |
| Hot-water flotation | nd | 79.6±0.0\(^a\) | 79.6±0.3\(^a\) | 78.8±0.0 | 78.8±0.9 | 76.1±0.0 | 70.2±4.3 | 73.6±0.3 | 3.5±0.0 | 3.4±0.0 | 3.4±0.0 | 3.5±0.0 |
| Arachidic (C20:0) | Solvent | 3.5± 0.1 | 3.5± 0.1 | 3.3±0.0 | 3.9±0.2 | 3.5±0.1 | 3.8±0.2 | 3.8±0.3 | 3.5±0.0 | 3.4±0.0 | 3.4±0.0 | 3.5±0.0 |
| Hot-water flotation | nd | 3.9±0.0 | 3.9±0.0 | 3.8±0.0 | 3.9±0.2 | 76.1±0.0 | 70.2±4.3 | 73.6±0.3 | 3.5±0.0 | 3.4±0.0 | 3.4±0.0 | 3.5±0.0 |
| Oleic (C18:1n9) | Solvent | 170.0±2.1 | 185.7±0.1 | 142.7±0.1 | 179.6±0.6 | 177.9±1.2 | 170.3±1.7 | 185.9±0.1 | 151.1±0.3 | 176.9±0.3 | 183.9±0.1 | 185.0±0.1 |
| Hot-water flotation | nd | 182.2±0.3 | 180.0±0.5 | 179.0±0.4 | 174.5±0.8 | 754.0±0.2 | 597.4±3.8 | 582.9±0.5 | 577.8±0.1 | 578.6±1.1 | 600.5±4.4 | 574.8±0.4 |
| Linoléic (C18:2n6) | Solvent | 576.0± 0.5 | 575.1± 0.1 | 614.8±0.7 | 580.4±0.3 | 580.1±6.9 | 577.4±2.9 | 574.0±0.2 | 597.4±3.8 | 582.9±0.5 | 577.8±0.1 | 578.6±1.1 |
| Hot-water flotation | nd | 568.1±0.4 | 569.8±0.1 | 571.2±2.2 | 570.8±4.6 | 574.0±0.2 | 597.4±3.8 | 582.9±0.5 | 577.8±0.1 | 578.6±1.1 | 600.5±4.4 | 574.8±0.4 |
| Linolénic (C18:3n3) | Solvent | 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 ± 0.0 |
| Hot-water flotation | nd | 1.4±0.1 | 1.4±0.1 | 1.4±0.0 | 1.4±0.0 | 1.3±0.2 | 1.3±0.1 | 1.2±0.2 | 1.4±0.1 | 1.4±0.1 | 1.4±0.1 | 1.4±0.1 |
| TSFAs | Solvent | 233.3 ± 0.5 | 233.3 ± 0.5 | 236.5 ± 0.3 | 232.6±2.2 | 231.2±0.9 | 233.5±0.5 | 241.9±3.2 | 233.7±0.2 | 232.7±0.1 | 233.0±0.5 | 242.6±0.4 |
| Hot-water flotation | nd | 242.9±0.8 | 243.0±0.8 | 244.0±2.0 | 241.7±0.4 | 244.0±2.1 | 243.0±1.7 | 224.5±2.9 | 224.6±2.9 | 224.6±2.9 | 224.6±2.9 | 224.6±2.9 |
| TMUFA | Solvent | 170.0 ±2.1 | 185.7 ± 0.1 | 142.7 ± 0.1 | 179.6 ± 0.6 | 177.9±4.8 | 170.3±1.7 | 185.9±0.7 | 151.1±0.3 | 176.9±0.3 | 183.9±0.1 | 185.0±0.1 |
| Hot-water flotation | nd | 182.2±3.3 | 180.0±0.5 | 179.0±0.4 | 174.5±0.8 | 181.0±0.1 | 184.6±0.5 | 166.2±2.5 | 175.6±2.0 |
| TPUFA | Solvent | 577.0 ± 0.5 | 576.2 ± 0.1 | 561.0±0.5 | 581.4±0.4 | 581.2±9.6 | 578.4±2.9 | 572.5±0.3 | 597.8±3.7 | 584.1±0.6 | 578.9±0.1 | 577.9±1.2 |
| Hot-water flotation | nd | 569.4±0.3 | 571.1±0.0 | 572.8±2.1 | 572.1±4.6 | 569.1±1.2 | 563.3±0.6 | 601.6±4.3 | 576.8±1.2 | 576.8±1.2 | 576.8±1.2 | 576.8±1.2 |

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: Arachidic acid; C18:1n9: Oleic acid; C18:2n6: Linoléic acid; C18:3n3: Linolénic 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⁻¹ 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 O₂ kg⁻¹ oil, value, which characterises most conventional oils. Indeed, in previous studies, Yong et al. (2006) showed that the lower peroxide values (10 meq O₂ kg⁻¹ 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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