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Chemical properties of fresh and roasted Sacha inchi kernel oil extracted by cold pressing method

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A study on physicochemical properties of Sacha Inchi (*Plukenetia volubilis L.*) kernel, Sacha inchi cake and Sacha inchi kernel oil was performed. The kernel was roasted at 120 ºC for 10 minutes and oil was extracted by mechanical cold press machine. Sacha inchi (SI) kernel and its cake were analysed for their amino acid composition and color attributes. Meanwhile, SI kernel oil was analyzed for tocopherol content, fatty acid and triacylglycerol (TAG) composition. From the results, leucine, lysine and valine were the main essential amino acids found in Sacha inchi kernel. Meanwhile, leucine, isoleucine, lysine and valine were the main essential amino acids in SI cake. Besides, gamma-tocopherol was the highest tocopherol contained in both fresh and roasted oil. The roasting process did not significantly affect ($p>0.05$) the tocopherol content in the SI kernel oil. However, the roasting temperature significantly affect ($p<0.05$) certain fatty acid and TAG composition of the oil. The highest fatty acid composition in SI kernel oil was linoleic acid (37.43-38.05%) and linolenic acid (43.22-44.35 %). This study suggested that Sacha inchi kernel, cake and oil could be used as functional food ingredients because it contains many beneficial nutrients.

Keywords: Sacha inchi, amino acid composition, fatty acid composition, triacylglycerol composition, tocopherol

INTRODUCTION

Sacha inchi (*Plukentia volubilis L.*) also known as the Inca peanut, is a perennial, oleaginous plant of the Euphorbiaceae family, native to the rain forest of the Andean region of South America (Guillen et al. 2003). The Sacha inchi plant produces star-shaped green fruits, which yield edible dark brown kernels. The kernels are rich in oil (35-60%) and protein (27%) and contain heat-labile substances with a bitter taste (Krivankova et al. 2007). In addition, the amino acid profile of the Sacha inchi (SI) protein fraction showed a relatively high level of cysteine, tyrosine, threonine and tryptophan, compared to other oilseed sources (Hamaker et al. 1992).

SI oil is characterized predominantly by high levels of essential fatty acids, namely linoleic and linolenic fatty acids, representing about 82% of the total oil content. Thus, linoleic and linolenic acid are very important for the prevention of coronary heart disease and hypertension (Simopoulos, 2011). The presence of other bioactive compounds, such as tocopherols, carotenes, polyphenolic compounds and phytosterols have been previously reported in SI oil (Follegatti-Romero et al. 2009). A wide range consumption of bioactive is important in our diet in terms of health. Tocopherols have vitamin E properties and display a strong antioxidant activity, conferring protection against lipid peroxidation in biological tissues and foods (Hounsome et al. 2008).

Besides, SI kernels are used in different forms by the Amazonian population. The oil is used in the preparation of various meals, the kernels are consumed roasted and the leaves are cooked and consumed. SI kernels are also used as a traditional remedy in the Amazon region to treat rheumatic problems and aching muscles (Fanali et al. 2011).

One major problem associated with Sacha inchi kernel oil is its potential oxidative instability due to the highly unsaturated nature of its oil. However, unrefined vegetable oils including Sacha inchi kernel oil are known to naturally contain antioxidant compounds that may give the oil protection against oxidation. Furthermore, Spielmeyer et al. (2009) stated that the roasting of safflower, sesame, and canola seeds has been shown to increase the oxidative stability of the extracted oil. Besides, the by-product which is the SI cake might also contain some valuable nutrient and minerals that would be useful as functional food ingredient (Zarinah et al. 2020). In addition, only a few papers have reported the composition of Sacha inchi oil and kernels. The significance of this study was to screen chemical properties of SI kernel, cake and its oil. The objectives of this study were to determine the amino acid composition and color attributes of SI kernel and its cake. Besides that, this study also aims to determine the tocopherol content, fatty acid and triacylglycerol composition of fresh and roasted SI kernel oil. This article aim to provide more information on the physicochemical properties of SI kernels to favor their promotion and consumption in local and international markets.

MATERIALS AND METHODS

Sample preparation

Sacha inchi kernel was supplied by Shane Ventures Sdn Bhd, Selangor. The kernel was roasted at temperature 120 ºC for 10 minutes according to method by Chirinos et al. (2016). The fresh and roasted kernels were extracted for their oil using mechanical cold press machine and oil was stored in sealed glass bottle at -20°C until analyzed according to method by Zarinah et al. (2014). Meanwhile, Sacha inchi pressed-cake was obtained after the oil extraction. The kernel and its cake were ground into powder prior to analysis.

Amino acid determination

Essential amino acids (methionine, histidine, phenylalanine, leucine, isoleucine, lysine, threonine, valine) and non-essential amino acids (arginine, aspartic acid, glutamic acid, serine, glycine, alanine, proline) content were analysed using AccQTag method and performed by High Performance Liquid Chromatography (HPLC) as described by Seo (2005).

Color analysis

The determination of color for four (4) samples (fresh kernel, roasted kernel, fresh cake, roasted cake) was done by using Chroma Meter CR-400 (Konica Minolta, Japan). The Chroma meter displayed three values which is L*, a* and b*. L* is an approximate measurement of luminosity, which is the property according to which each color can be considered as equivalent to a member of the greyscale, between black and white (Granato & Masson, 2010). Parameter a* measures the red coloration of fruits, which is caused due to the predominant amount of carotenoid lycopene and parameter b* measures the orange colorant of fruits due to β-carotene (Sacks & Francis, 2001).

Tocopherol content

Tocopherols were analyzed by using HPLC (Varian Pro-Star HPLC, Varian Inc., Walnut Creek, CA, USA) according to the ISO standard method (ISO, 2006). An aliquot (0.1 g) from each oil sample was weighed into a 10-mL volumetric flask and diluted with n-hexane. Detection was performed by using a fluorescence detector at 290 nm excitation wavelength and 330 nm emission wavelength.

Fatty acid composition

The saturated and unsaturated fatty acid composition in SI kernel oil was determined according to MPOB test method (2005).

Triacylglycerol (TAG) composition

The TAG composition was determined according to MPOB test method (2005).

Statistical analysis

All assays were carried out in triplicates. Data were reported as mean ± standard deviation. Mean comparisons were conducted by t-test, using the SPSS Software version 20.

RESULTS AND DISCUSSION

Amino acid composition

Table 1 shows the amino acid profile of fresh and roasted Sacha inchi kernel. The result indicates that leucine (2.55 %), lysine (2.13 %) and valine (2.28 %) were the major essential amino acid in fresh kernel while roasted kernel contained major amount of leucine (2.73 %) and valine (2.37 %). It also contained other essential amino acids such as methionine, histidine, phenylalanine, isoleucine and threonine. Histidine was reported to be highly essential for development of children. The result generally suggests that the diet of kernels may not contribute largely to the supply of essential amino acids as other edible seeds but can supply appreciable amount of essential amino acids needed for body development (Ogungbenle et al. 2013).

Table 1:Amino acid composition of Sacha inchi kernel

Type of amino acid	Fresh kernel (%)	Roasted kernel (%)
Essential amino acid		
Methionine (met)	0.42 ± 0.02[a]	0.41 ± 0.02[a]
Histidine (his)	1.13 ± 0.19[a]	1.00 ± 0.02[a]
Phenylalanine (phe)	1.01 ± 0.04[a]	1.07 ± 0.04[a]
Leucine (leu)	2.55 ± 0.06[a]	2.73 ± 0.06[a]
Isoleucine (ile)	1.81 ± 0.04[a]	1.94 ± 0.04[a]
Lysine (lys)	2.13 ± 0.07[a]	1.80 ± 0.03[b]
Threonine (thre)	1.70 ± 0.09[a]	1.74 ± 0.04[a]
Valine (val)	2.28 ± 0.03[a]	2.37 ± 0.05[a]
Non-essential amino acid		
Arginine (arg)	4.19 ± 0.02[a]	4.23 ± 0.04[a]
Aspartic acid (asp)	4.55 ± 0.11[a]	4.46 ± 0.06[a]
Glutamic acid (glu)	5.18 ± 0.40[a]	5.07 ± 0.22[a]
Serine (ser)	2.73 ± 0.17[a]	2.48 ± 0.02[a]
Glycine (gly)	6.04 ± 0.05[a]	5.63 ± 0.23[a]
Alanine (ala)	1.60 ± 0.02[a]	1.46 ± 0.13[a]
Proline (pro)	1.53 ± 0.04[a]	1.63 ± 0.04[a]
Total amino acids	38.85± 0.12[a]	38.01 ± 0.12[b]

Values are mean ± standard deviation in triplicates Determinations

Values followed by different letter in same row are significantly different at $p<0.05$.

Based on Table 1, it was observed that there was no significant difference ($p>0.05$) of essential amino acid content between fresh and roasted kernel except for lysine. This is because lysine is a particularly reactive amino acid due to its free *ε*-amino group causing the lysine content to decrease after the kernel was roasted to 120 ºC. This result was in agreement with findings from Kristin et al. (2012) which reported that lysine content in peanut decreased from fresh to roasted samples. Besides that, there was significant difference ($p<0.05$) of total amino acids between fresh and roasted kernel which indicates that the roasting process degraded the amino acid content in the kernels. The kernels also contained non-essential amino acids such as arginine, aspartic acid, glutamic acid, serine, glycine, alanine and proline. No significant difference of non-essential amino acids was observed between fresh and roasted kernel. This indicates that the roasting process did not affected the non-essential amino acid content and maintains the availability of bioactive compound in both kernels as reported by Chirinos et al. (2016). The amino acid composition of fresh and roasted Sacha inchi pressed-cake were shown in Table 2. Both of them were rich in leucine (3.84 - 4.04 %) and valine (3.41 – 3.53 %).

Other minor amount of essential amino acids in both cakes were histidine, phenylalanine, isoleucine, lysine and threonine. The lowest amount of essential amino acids in both cakes was methionine which is similar with the findings from Saroat et al. (2016). Ruiz et al. (2013) reported that essential amino acid content of Sacha inchi was adequate as recommended by the FAO/WHO except for lysine and leucine. For non-essential amino acid, the highest content was glutamic acid in both samples. Significant amount of glutamic acid, glycine and alanine were also found in fresh and roasted Sacha inchi cake. This is might due to Maillard reaction during roasting that modified the protein structure (Saalia & Phillips, 2011).

Table 2: Amino acid composition of Sacha inchi kernel cake

Type of amino acid	Fresh cake (%)	Roasted cake (%)
Essential amino acid		
Methionine (met)	0.64 ± 0.03[a]	0.62 ± 0.03[a]
Histidine (his)	1.31 ± 0.01[a]	1.25 ± 0.01[a]
Phenylalanine (phe)	1.50 ± 0.07[a]	1.43 ± 0.07[a]
Leucine (leu)	4.04 ± 0.17[a]	3.84 ± 0.17[a]
Isoleucine (ile)	2.90 ± 0.11[a]	2.77 ± 0.11[a]
Lysine (lys)	2.75 ± 0.17[a]	2.90 ± 0.17[a]
Threonine (thre)	2.49 ± 0.07[a]	2.63 ± 0.07[a]
Valine (val)	3.53 ± 0.08[a]	3.41 ± 0.08[a]
Non-essential amino acid		
Arginine (arg)	6.21 ± 0.03[a]	6.13 ± 0.03[a]
Aspartic acid (asp)	6.55 ± 0.11[a]	6.73 ± 0.11[a]
Glutamic acid (glu)	7.74 ± 0.00[a]	7.72 ± 0.00[b]
Serine (ser)	3.45 ± 0.08[a]	3.55 ± 0.08[a]
Glycine (gly)	6.35 ± 0.02[a]	6.19 ± 0.02[b]
Alanine (ala)	2.10 ± 0.00[a]	2.15 ± 0.00[b]
Proline (pro)	2.36 ± 0.07[a]	2.26 ± 0.07[a]
Total amino acids	53.93±0.12[a]	53.58±0.12[a]

Values are mean ± standard deviation in triplicates determinations
Values followed by different letter in same row are significantly different at $p<0.05$

Color attributes

The results of color analysis for fresh and roasted Sacha inchi kernel was shown in Table 3. There was a significant difference ($p<0.05$) between the L*, a* and b* values of both kernels. From the results, L* value of fresh kernel is higher (54.28) than roasted kernel (48.77) indicates that the color of fresh kernel is brighter. Moss and Otten (1989) reported that color changes during roasting are mainly related to drying and non-enzymatic browning. The color changes due to the formation of browning has often been associated with the Maillard reaction (Baini & Langrish, 2009). Generally, melanoidins are formed from Maillard reaction and are known to possess pronounced antioxidant properties, thereby improving the oxidative stability of nuts and seeds (Rizzi, 2003).

Table 3: Color analysis of Sacha inchi kernel

Sample	Fresh kernel	Roasted kernel
L*	54.28 ± 1.10[a]	48.77 ± 0.88[b]
a*	2.28 ± 0.03[a]	2.01 ± 0.04[b]
b*	21.35 ± 0.30[a]	19.12 ± 0.47[b]

Values are mean ± standard deviation in triplicates determinations
Values followed by different letter in same row are significantly different at $p<0.05$

Despite the variation in color systems, the redness component which is a* value, is reported to be proportional to the carotenoid concentration (Choubert, 1982). The a* value in roasted kernel is lower than fresh kernel then it might indicates that the carotenoid concentration was decreasing in roasted kernel. The roasting process might cause the reduction of carotenoid in the Sacha inchi kernel. The results can be supported with findings by Konsoula (2010) that reported the heating process, such as roasting, could also degrade the polyphenols and antioxidant capacity (DPPH assay) in sesame seeds and its oil.

Table 4 showed the results of color analysis for fresh and roasted Sacha inchi cake. L* value decreased after roasting process which resulted from non-enzymatic browning (Ozdemir & Devres, 2000). The a* value shows redness for food products and the increasing in the a* value of roasted cake was due to formation of brown pigments through the non-enzymatic browning and phospholipids degradation. Kahyaoglu and Kaya (2006) reported that increase in the a* value during roasting was correlated with decrease in the L-value. This report could support the results obtained from this study as a* value of Sacha inchi cake increase with the decrease in L* value. The results also could be supported with findings by Skrede & Storebakken (1986) whereby they stated that the increase in redness (a* value) and decrease in lightness (L* value) with increasing carotenoid concentration.

Table 4: Color analysis of Sacha inchi kernel cake

Sample	Fresh cake	Roasted cake
L*	54.19 ± 0.22[a]	43.59 ± 1.10[b]
a*	1.87 ± 0.03[a]	4.03 ± 0.15[b]
b*	16.70 ± 0.08[a]	23.79 ± 0.34[b]

Values are mean ± standard deviation in triplicates
determinations
Values followed by different letter in same row are significantly different at $p<0.05$

Tocopherol content

Table 5 showed the tocopherol content of fresh and roasted Sacha inchi kernel oil. No significant difference ($p>0.05$) of the tocopherol content was observed between fresh and roasted sample. This indicates that the roasting process did not affect the tocopherol content in oil. The highest tocopherol in both oil samples was γ-Tocopherol (1279.50 – 1288.00 ppm), followed by δ-Tocopherol, α-Tocopherol and β-Tocopherol. The greater amounts of γ- and δ-tocopherols with respect to α-tocopherols could be attributed to their greater antioxidant capability causing the oil more stable to oxidation (Follegatti-Romero et al. 2009). Besides, Ruperez et al. (2001) reported that the intestinal absorption of γ-tocopherol is similar to that of α-tocopherol, and it could play a specific role in preventing side effects of some radicals like peroxynitrite.

The total tocopherols for roasted Sacha inchi kernel oil was higher than fresh oil which is 1863.50 ppm and 1862.50 ppm respectively. Increasing tocopherol content occurs by increased efficiency of extraction from the cellular structure (Murkovic et al. 2004). Tocopherols are recognized as potent antioxidants. Schmidt and Pokorny (2005) indicate that the tocopherol antioxidant activity in lipid systems follows this order: $\gamma > \delta > \alpha > \beta$; thus, the high content of γ-tocopherol and δ-tocopherol in Sacha inchi kernel oil constitutes a factor of antioxidant protection for the seed and the extracted oil. According to Wee-sim et al. (2007), the β- and δ-tocopherol were not detected in the cold-pressed flaxseed oils compared to Sacha inchi kernel oil whereby all four tocopherols (α, β, γ and δ) were detected in this study. This shows that Sacha inchi kernel oil might be a better source of tocopherol compared to flaxseed oil.

Table 5: Tocopherol content of Sacha inchi kernel oil

Tocopherol (ppm)	Fresh Sacha Inchi kernel oil	Roasted sacha inchi kernel oil
α-Tocopherol	5.00 ± 0.00[a]	6.00 ± 0.00[a]
β-Tocopherol	1.00 ± 0.00[a]	1.00 ± 0.00[a]
γ-Tocopherol	1279.50 ± 7.78[a]	1288.00 ± 1.41[a]
δ-Tocopherol	577.00 ± 2.83[a]	568.50 ± 0.71[a]
Total tocopherols	1862.50 ± 4.95[a]	1863.50 ± 0.71[a]

Values are mean ± standard deviation in triplicates
determinations
Values followed by different letter in same row are significantly different at p<0.05

Fatty acid composition

The fatty acid composition of Sacha inchi kernel oil was reported in Table 6. The highest percentage of fatty acid were linoleic acid (omega 6) (37.43 - 38.05 %) and linolenic acid (omega 3) (43.22 - 44.35 %). These results are in good agreement with those reported by other groups (Gutierrez et al. 2011). The high significant content of polyunsaturated essential fatty acids (omega 3 and omega 6) causing Sacha inchi kernel oil being advertised as a nutritional supplement as it may provide more useful nutraceuticals than other common seed oils which contain only remarkable quantities of omega 6 fatty acids. Other fatty acids present in Sacha inchi kernel oil were palmitic acid, palmitoleic acid, stearic acid, elaidic acid, oleic acid, linoelaidic acid and arachidic acid. The oleic acid in Sacha inchi kernel oil (9.95 - 10.28%) were found lower than pili nut oil (50.7 – 52.59 %) (Zarinah et al. 2014).

Flaxseed oil contains linolenic acid (47 %), which comparable to that of Sacha inchi kernel oil (43.22 %), together with low percentages of saturated fatty acids such as palmitic and stearic acid. Plant oils that are rich in polyunsaturated fatty acids could be a great interest for a balanced diet and a good alternative to fish-based foods which is the main food sources of omega 3 fatty acids (Singh et al. 2011).

Table 6: Fatty acid composition of Sacha inchi kernel oil

Fatty acid (%)	Fresh Sacha inchi kernel oil	Roasted Sacha inchi kernel oil
Palmitic acid (C16:0)	4.46 ± 0.01[a]	4.36 ± 0.00[b]
Palmitoleic acid (C16:1)	0.07 ± 0.01[a]	0.07 ± 0.00[a]
Stearic acid (C18:0)	3.41 ± 0.03[a]	3.30 ± 0.00[b]
Elaidic acid (C18:1t)	0.03 ± 0.00[a]	0.03 ± 0.00[a]
Oleic acid (C18:1)	10.28 ± 0.01[a]	9.95 ± 0.01[b]
Linoelaidic acid (C18:2t)	0.07 ± 0.00[a]	0.08 ± 0.01[a]
Linoleic acid (C18:2)	38.05 ± 0.01[a]	37.43 ± 0.04[b]
Linolenic acid (C18:3)	43.22 ± 0.04[a]	44.35 ± 0.07[b]
Arachidic acid (C20:0)	0.24 ± 0.00[a]	0.24 ± 0.04[a]

Values are mean ± standard deviation in triplicates determinations
Values followed by different letter in same row are significantly different at p<0.05

Polyunsaturated fatty acids (PUFA) of the SI kernel oil amounted to about 81% of the total fatty acids, while the monounsaturated (MUFA) and saturated (SFA) fatty acids were about 10% and 8%, respectively. The high content of MUFAs and PUFAs were considered healthy fats in nuts oil content which can counterbalance the unfavorable SFAs (Ros & Mataix, 2006). Even though the high ratios of PUFA/MUFA are very good for human health, they could make the SI kernel oil very susceptible to oxidation. However, recent studies by Follegatti-Romero et al. (2009) indicate that SI kernel oil contains high amounts of γ- and δ-tocopherols (1.14 and 1.25 g/kg, respectively), which could increase resistance against oxidation because they are the most active antioxidants in lipids. In addition, microencapsulation using spray-drying technique could also be used to prevent the oxidation of unsaturated fatty acids and to avoid the formation of off-flavors of the oil (Gharsallaoui et al. 2007).

The ratios of omega 6/omega 3 fatty acid of both sample were 0.84 - 0.88. This range was close to the values of 0.81 which reported in study by Gutiérrez et al. (2011) for SI kernel oil. Several sources of information suggest that the human diet should consume oil with omega 6/omega 3 ratio of about one. Thus, consumption of SI kernels or its oil would be beneficial in terms of health because it is high in linolenic acid and has low omega 6/omega 3 ratio (Simopoulos, 2011).

From the results, there were significant different ($p<0.05$) of palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid in fresh roasted Sacha inchi kernel oil. This can be supported by findings from Lee et al. (2004) which stated some food-processing techniques could affect fatty acid composition of oils when subjected to successive heating. Types of reaction that are known to lead to degradation of vegetable oils include polymerisation, oxidation and hydrolysis. However, roasting triggered an increase in linolenic acid content of the roasted SI kernel compared to the fresh SI kernel with values of 43.22 to 44.35 %. The roasting conditions favored the dilatation of the plant cells of the kernels facilitating the extraction of the oil and thus of the fatty acids (Chirinos et al. 2016). No significant difference was observed between fresh and roasted oil in terms of palmitoleic acid, elaidic acid, linoelaidic acid and arachidic acid. Cisneros et al. (2014) reported that roasting process did not trigger substantial changes in the fatty acid profile of the oil. Additionally, Epaminondas et al. (2011) found that roasting of flaxseed (~43.2% α-linolenic acid in the oil) at 160 ºC for 15 minutes did not induce substantial changes in the fatty acid composition.

Triacylglycerol (TAG) composition

As reported in Table 7, sixteen (16) different TAGs were detected in fresh and roasted Sacha inchi kernel oil. Besides that, there were significant difference of few TAG components in both samples indicate that the roasting process affected the TAG composition. From Table 7, some coelutions were observed (LLP + SLLn + POLn, SLL + OLP + SOLn and SLO+SLP). These results might be related with the increasing of TAG retention times with the increasing of partition number (PN). PN defined as the total carbon number (CN) in all acyl chains minus two times the number of double bonds (DBs). As a consequence, TAGs with the same PN are very difficult to resolve. In addition, the retention behavior of TAGs with the same CN is strongly influenced by the fatty acid composition of the individual TAG, mainly by the unsaturation degree and acyl chain length (Lisa & Holcapek, 2008).

In agreement with the fatty acid composition of SI kernel oil, identified TAGs contained five different fatty acids which were P (palmitic), L (linoleic), Ln (linolenic), O (oleic), and S (stearic). The dominant components (18.95-19.83 %) were identified as dilinolenoyl-linoleoylglycerol (LnLLn) and dilinoleoyl-linolenoylglycerol (LLnL). Most of the TAGs in Sacha inchi kernel oil contained at least one residue of linolenic acid. The high percentage of linolenic acid in TAGs is very important because unsaturated fatty acids deriving primarily from vegetable oils reduce the levels of total and low density lipoprotein cholesterol which will reduce the risk of cardiovascular diseases (Berryman et al. 2011).

Table 7: TAG composition of Sacha inchi kernel oil

Component (%)	Fresh Sacha inchi kernel oil	Roasted Sacha inchi kernel oil
LnLnLn	7.94 ± 0.07[a]	8.64 ± 0.02[b]
LnLLn	19.06 ± 0.02[a]	19.83 ± 0.07[b]
LLnL	19.27 ± 0.23[a]	18.95 ± 0.17[a]
LnOLn	5.44 ± 0.28[a]	5.99 ± 0.13[a]
PLnLn	2.79 ± 0.04[a]	2.81 ± 0.09[a]
LLL	6.60 ± 0.02[a]	6.40 ± 0.03[b]
OLLn	10.33 ± 0.05[a]	10.05 ± 0.03[b]
PLLn	7.30 ± 0.04[a]	7.28 ± 0.05[a]
SLnLn	0.05 ± 0.00[a]	0.05 ± 0.00[a]
LOL	4.43 ± 0.14[a]	4.19 ± 0.09[a]
OLnO	1.37 ± 0.03[a]	1.22 ± 0.06[a]
LLP+SLLn+POLn	8.33 ± 0.02[a]	8.14 ± 0.03[b]
OLO	1.07 ± 0.02[a]	0.98 ± 0.01[b]
SLL+OLP+SOLn	3.89 ± 0.03[a]	3.67 ± 0.01[b]
OOO	0.22 ± 0.01[a]	0.20 ± 0.01[a]
SLO+SLP	1.24 ± 0.02[a]	1.04 ± 0.06[b]

Values are mean ± standard deviation in triplicates determinations
Values followed by different letter in same row are significantly different at $p<0.05$

CONCLUSION

Sacha inchi kernel and cake contain many essential amino acids. Therefore it is suggested that both kernel and cake could be a useful ingredients for human consumption. Roasting process applied to Sacha inchi kernels at 120 ºC affected the color attributes of fresh and roasted kernel as well as its cake. Both oil samples (fresh and roasted Sacha inchi kernel oil) have high total tocopherol content which could provide better antioxidant properties than other oils. Sacha inchi kernel oil, contained mainly of essential fatty acids (omega-3 and omega-6). The roasting process affect some of the fatty acids in Sacha inchi kernel oil such as palmitic acid, stearic acid and oleic acid. LnLLn and LLnL were the major TAG components in Sacha inchi kernel oil. The good functionality of the Sacha inchi kernel, cake and oil indicates its potential usefulness in various applications.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

FSR designed and performed the experiments and also wrote the manuscript. ZZ supervised the experiments, gave guidance during data analysis and reviewed the manuscript. AHAT, NH, NS, CAAB and HH supervised the experiments.

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