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Oxidative quality of commercial fried nuts: evaluation of a surface and an internal lipid fraction

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RESUMEN

Calidad oxidativa de frutos secos comercializados: evaluación de las fracciones lipídicas superficial e interna

En este estudio se evalúa la calidad oxidativa de muestras comerciales de frutos secos fritos mediante el análisis independiente de dos fracciones lipídicas, el aceite superficial, fácilmente extraíble con disolventes orgánicos, y la fracción de lípidos internos. Las muestras estudiadas fueron 6 muestras de almendras, 10 muestras de cacahuetes, 4 muestras de pipas de girasol y 2 muestras de anacardos. Se analizaron el contenido de aceite, el índice de peróxidos, el contenido de polímeros y la composición de ácidos grasos. Los resultados mostraron dos fracciones lipídicas con diferente estado de oxidación. Mayores niveles de oxidación fueron normalmente encontrados en la fracción más expuesta al aire, aunque estados de oxidación considerablemente más altos en la fracción interna fueron también detectados en varias muestras. La calidad oxidativa fue también evaluada en muestras seleccionadas de cada fruto seco que fueron almacenadas durante 1 año a temperatura ambiente y a la oscuridad. Solamente las almendras y los anarcados presentaron tras el almacenamiento una calidad oxidativa aceptable. Por otra parte, un estudio sobre los cambios debido a la fritura y la contribución del aceite de fritura a los lípidos de los frutos secos fritos indicó que la composición del aceite superficial puede ser modificada mediante la incorporación de cantidades importantes del aceite de fritura. Por tanto, el aceite de fritura puede afectar la calidad y la estabilidad oxidativa del aceite superficial.

PALABRAS-CLAVE: Almendras - Anacardos - Cacahuetes - Calidad oxidativa - Pipas de girasol.

SUMMARY

Oxidative quality of commercial fried nuts: evaluation of a surface and an internal lipid fraction

The oxidative quality of commercial fried nuts was evaluated by independent analyses of two lipid fractions, the surface oil, and the internal lipid fraction. The nuts studied were 6 samples of almonds, 10 samples of peanuts, 4 samples of sunflower seeds and 2 samples of cashew nuts. The oil content, peroxide value, polymer content, and fatty acid composition were analyzed. The results showed two lipid fractions with different oxidation status. Higher oxidation levels were normally found in the oil fraction more exposed to air, although considerably higher oxidation status in the internal oil was also detected in various samples. Oxidative quality was also evaluated in selected samples of each nut after 1 year of storage at room temperature, in the dark . Only the almonds and cashew nuts exhibited acceptable oxidative quality after storage. In addition, a study on the changes due to frying and the contribution of the frying oil to the lipids in the final product showed that the composition of the surface oil can be changed by the incorporation of substantial contents of the frying fat. Consequently, the frying fat may exert some effect on the oxidative quality and oxidative stability of the surface oil.

KEY-WORDS: Almonds - Cashew nuts - Oxidative quality - Peanuts - Sunflower seeds

1. INTRODUCTION

Frying is a process widely applied in the industrial preparation of an increasing number of foods. Among them, the production of nuts by frying is an alternative process to dry roasting. These products of high added value are the preferred snacks for exporting purposes (Moreiras et al., 1999).

One of the main advantages of frying against dry roasting of nuts lies in the possibility of protecting the surface of the product against oxidation during storage by the incorporation of oil (the frying oil) with higher stability than that of the nut lipids. In a previous paper, we reported results on the industrial discontinuous frying of almonds, peanuts and sunflower seeds (Marmesat et al, 2005). Frying was carried out to define both the main changes undergone by the food and also the frying performance of high-oleic high-palmitic sunflower oil, a genetically modified oil of high thermoxidative stability (Márquez-Ruiz et al., 1999; Guinda et al., 2003). Changes in the oil stability of the food due to the frying process clearly demonstrated the interest of using frying oils with high oxidative stability. Previous studies on quality (Metwalli et al., 1975 a, 1975 b) and oxidative stability during storage (El-Kayati et al., 1988; Mate et al., 1996; Mugendi et

al., 1998; Bolton et al., 2002; García Pascual et al., 2003) of roasted nuts are of interest. Nevertheless, the influence of the lipid distribution in these products on their quality and oxidative stability was not taken into account. The lipid distribution in nuts is such that two lipid fractions can be distinguished. A minor lipid fraction is not bound to the matrix and easily extractable with organic solvents such as hexane. The major lipid fraction comprises lipid droplets immersed into the matrix and constitutes a noncontinuous lipid phase whose extraction requires the rupture of the nut matrix. Thus, only a small part of the lipids in nuts is in direct contact with air, while oxygen must be transported across the matrix to reach the noncontinuous lipid phase. Consequently, external quality and oxidation status might be different from those in the noncontinuous lipid phase.

In an excellent report, Fritsch pointed out the problems of oxidation associated with the lipid distribution in foods. Organoleptically detectable lipid oxidation can occur in foods containing a noncontinuous lipid phase if the external lipids are oxidized, even though they are present at levels as low as 0.5%. Thus, the product is unacceptable and it would be rejected with a very low oxidation level. From an analytical point of view, such a low oxidation status might not be detected if total lipids are analyzed (Fritsch, 1994).

The objective of this study was to evaluate the oxidative quality of commercial fried nuts by independent analyses of the surface and internal lipid fractions. The samples studied were almonds, peanuts, sunflower seeds and cashew nuts. Peroxide value, as representative of primary oxidation products, and polymers content, as representative of frying fat degradation, were determined in both lipid fractions. Perception of rancidity in the fried nuts by three untrained tasters and the oxidative stability index of the total oil by the Rancimat device were also analyzed. Oxidative quality was also evaluated in select samples after 1 year of storage at room temperature, in the dark. Furthermore, changes due to frying and the contribution of the frying oil to the lipids in the final product were studied in almonds, peanuts and sunflower seeds. Thus, the composition of commercial nuts fried in palm olein was compared to that of the raw nuts.

2. EXPERIMENTAL PROCEDURES

2.1. Samples and treatments

Commercial fried nuts from different companies were acquired locally. They corresponded to 6 samples of almonds, 10 samples of peanuts, 4 samples of sunflower seeds and 2 samples of cashew nuts. In addition, almonds, peanuts and sunflower seeds fried in palm olein as well as the corresponding raw nuts were supplied by SALYSOL S.A. All the samples were kept at –20 °C until analysis.

Selected samples of commercial fried nuts were stored at room temperature in the dark for a period of 1 year. At the time of storage it was 1 year until the maximum period for consumption for the samples of almonds, peanuts and cashew nuts according to the labels; while it was 9 months for the selected sample of sunflower seeds.

2.2. Moisture content

Moisture was determined gravimetrically by freeze-drying 20 g of ground samples of fried or raw nuts.

2.3. Lipid extraction procedures

The total amount of lipids in the nuts was determined by Soxhlet extraction, applying an extraction period of 6 h and diethyl ether as solvent (AENOR, 1991). Then, the solvent was evaporated under vacuum in a rotary evaporator and the extracted oil was dried to a constant weight using a stream of nitrogen.

The surface oil fraction was extracted according to Sankarikutty *et al.* (1988). Thus, 100 mL of light petroleum (60-80 °C) was added to 10 g of intact sample. Stirring of the sample was applied at room temperature for 15 min. Then, after filtration through filter paper, the solvent was evaporated under vacuum in a rotary evaporator and the extracted oil was dried to a constant weight using a stream of nitrogen.

After removal of the surface oil, the nut sample was ground and the internal oil was extracted following the same procedure described above for the total lipid fraction.

2.4. Dry lipid-free matter content

The content of dry lipid-free matter was calculated by the subtraction of moisture and lipid contents from the weight of intact samples.

2.5. Analysis of polymers

Polymers were determined by high performance size exclusion chromatography (HPSEC) following the IUPAC Standard Method 2.508 (IUPAC, 1992). Oil samples were diluted at 40-50 mg/mL in tetrahydrofuran and analyzed directly in an HPSEC chromatograph. The chromatograph was equipped with a Rheodyne 7725i injector with a 10-µL sample loop, a Waters 510 HPLC pump (Waters Associates, Milford, MA, USA), two 100 and 500 Å Ultrastyragel columns connected in series (Waters Associates, Milford, MA, USA), 25 cm x 0.77 cm I.D., packed with a porous, highly cross-linked styrenedivinylbencene copolymer (< 5µm), and a refractive index detector (Agilent Technologies, CA, USA).

2.6. Fatty acid composition

The fatty acid composition was determined by GC after derivatization to fatty acid methyl esters with 2N KOH in methanol at room temperature, according to the IUPAC Standard Method (IUPAC, 1992).

2.7. Peroxide value

The peroxide value (PV) was determined through the iodometric assay according to the AOCS standard method (AOCS, 1994).

2.8. Oil stability index

The oil stability index (OSI) was determined in a Rancimat apparatus following the AOCS standard method (AOCS, 1994). The nut samples were ground and the amount used was 5 g. Results were obtained at 110 °C with an air flow of 20 L h^{-1}.

2.9. Detection of rancidity

Rancid flavor and rancid odor when opening the product package were determined by three untrained tasters. The sample was considered rancid when at least 2 of the tasters clearly detected the stated attribute.

2.10. Statistical analysis

The statistical analysis was performed by Microsoft Excel 2000 (Microsoft Co., WA, USA). Comparisons between means were made by the Student's *t* test. Significance was defined at $P < 0.05$.

3. RESULTS AND DISCUSSION

Tables 1 to 3 list the results of physico-chemical parameters obtained in the commercial fried nuts. The physico-chemical parameters studied were the contents of the surface and internal oil fractions, PV and polymers content in both the surface and internal oils, and the OSI of the total oil.

The content of the surface oil fraction was not statistically different between the nuts, showing values within 5.5-13.7 g/100 g of nuts. Similarly, no significant differences were found in the contents of the internal oil fraction, varying between 31.2 and 49.0 g/100 g of nuts. Table 4 summarises the average composition of the nuts.

PV showed considerably variable results in both oil fractions within each nut. As an example, the PV was within 8.9-39.8 meq/kg of oil in the surface oil of the peanuts. The PV was not higher than 56 meq/kg of oil in the surface oil of all the nuts, which may explain that none of the samples tested showed rancid odor when opening the product package. With few exceptions, PV was higher in the fraction more exposed to air, i.e., the surface oil, in relation to the corresponding internal fraction. On the contrary, the opposite can occur and exceptional values as high as 160 meq/kg of oil in the internal oil (sample P8 in Table 2) can be found in samples with no objectionable odor. In the case of sample P8, although no rancid odor was detected, extreme rancid flavor was however perceived by the tasters when the internal oil was released into the mouth. Similar results from shelf-life tests in corn fried in hydrogenated soybean shortening were reported by Fritsch (1994). The higher oxidative stability of the surface fraction was attributed to the higher stability of the frying fat, incorporated into the product in the frying process, in relation to the corn lipids.

Table 1
Physico-chemical characteristics of surface and internal oils from commercial fried almonds

SAMPLE	Oil Fraction	Oil (wt % on nut)	PV (meq/kg of oil)	Polymers (wt % on oil)	OSI (h)
A 1	Surface	11.1	5.6	0.2	18.5
	Internal	40.2	2.9	0.0	
A 2	Surface	12.5	15.1	0.3	16.4
	Internal	44.1	7.7	0.0	
A 3	Surface	7.2	10.2	0.9	15.2
	Internal	35.7	14.3	0.0	
A 4	Surface	9.0	11.8	0.1	19.5
	Internal	42.2	2.2	0.0	
A 5	Surface	6.4	20.5	1.2	9.8
	Internal	45.7	20.6	0.1	
A 6	Surface	12.9	9.4	0.4	21.4
	Internal	45.2	1.5	0.0	

The content of polymers in the surface oil showed variable results that oscillated in the 0.1-4.2 % range. In the case of the internal oil, the content of polymers was very low or not detectable. In conjunction with the relatively low PV found in the surface fraction, the results of polymers clearly indicated that the occurrence of variable contents of polymers in the surface oil were due to frying oil degradation.

Table 2
Physico-chemical characteristics of surface and internal oils from commercial fried peanuts

SAMPLE	Oil Fraction	Oil (wt % on nut)	PV (meq/kg of oil)	Polymers (wt % on oil)	OSI (h)
P 1	Surface	9.1	22.2	0.7	11.2
	Internal	40.2	10.6	0.0	
P 2	Surface	8.3	39.8	0.8	2.7
	Internal	42.1	27.6	0.0	
P 3	Surface	10.5	38.0	1.3	6.4
	Internal	42.2	18.3	0.2	
P 4	Surface	6.5	8.9	0.7	14.2
	Internal	47.5	10.3	0.0	
P 5	Surface	9.2	18.4	0.1	> 45
	Internal	37.0	10.6	0.0	
P 6	Surface	7.8	26.3	0.7	6.7
	Internal	31.8	47.8	0.0	
P 7	Surface	10.7	32.4	1.3	10.6
	Internal	39.3	39.1	0.2	
P 8	Surface	9.2	24.5	0.6	1.4
	Internal	42.7	160	1.7	
P 9	Surface	8.9	12.0	0.5	18.4
	Internal	31.2	4.8	0.0	
P 10	Surface	10.2	15.4	2.3	17.5
	Internal	34.6	7.2	0.0	

Table 3
Physico-chemical characteristics of surface and internal oils from commercial fried sunflower seeds (S) and cashew nuts (C)

SAMPLE	Oil Fraction	Oil (wt % on nut)	PV (meq/kg of oil)	Polymers (wt % on oil)	OSI (h)
S 1	Surface	9.4	55.4	1.3	2.2
	Internal	36.5	34.2	0.4	
S 2	Surface	8.1	52.9	2.3	1.5
	Internal	43.8	89.5	0.8	
S 3	Surface	5.5	14.1	4.2	4.8
	Internal	49.0	8.5	0.7	
S 4	Surface	9.7	27.2	3.4	4.6
	Internal	38.8	20.8	0.3	
C 1	Surface	13.7	3.3	0.4	> 45
	Internal	47.3	1.8	0.0	
C 2	Surface	10.2	6.4	0.2	> 45
	Internal	37.8	1.6	0.0	

Table 4
Summary of oil composition (wt %) in the commercial samples of nuts and seeds

SAMPLE	Oil Fraction	Mean	Standard Deviation	Number of Samples
ALMONDS	Surface	9.8[a]	2.5	6
	Internal	41.6[b]	3.5	
PEANUTS	Surface	9.0[a]	1.7	10
	Internal	38.9[b]	5.0	
SUNFLOWER SEEDS	Surface	8.2[a]	1.7	4
	Internal	42.0[b]	4.8	
CASHEW NUTS	Surface	11.9[a]	1.8	2
	Internal	42.6[b]	4.7	

Means with different superscript letters are significantly different.

The stability against oxidation of the total oil from nuts as measured by the OSI was dependent on the nut and the oxidation status. Thus, for similar oxidation levels the almonds and cashew nuts were the most stable samples. Within the samples of the same nut, the OSI decreased with an increase in PV, which can be easily calculated for the total oil by taking the PVs and oil contents of the surface and internal fractions.

The fatty acid composition of both the surface and internal oils is given in Tables 5-7. The frying fat used in the industrial preparation as declared by the manufacturer on the label has also been included. In general, no substantial differences were found in the fatty acid composition of the surface and internal fractions. Significant differences were only observed in the case of samples fried in palm olein. In particular, these differences were noted in a higher content of C16:0 in the surface oil (samples A3, A5, P4, P7 and S4).

The differences in oxidative stability (OSI) between the nuts were consistent with the fatty acid composition of the nut lipids, mainly represented by the internal fraction (Tables 5-7). Thus, the more stable samples were those with lower contents of the more unsaturated fatty acid (C18:2), i.e. the almonds and cashew nuts.

Oxidative quality was also evaluated in selected samples of each nut after 1 year of storage at room temperature in darkness conditions. At the time of storage it was 1 year until the maximum period for consumption in the samples of almonds, peanuts and cashew nuts, while it was 9 months in the selected sample of sunflower seeds. All the samples were acceptable by the tasters at the time of storage. Results of the initial and stored samples are listed in Table 8.

Only, the almonds and cashew nuts were acceptable by the tasters after 1 year of storage. Relatively low increases in PV were observed in the

Table 5
Major fatty acids (%) in surface and internal oils from commercial fried almonds

SAMPLE	Oil Fraction	C 16:0	C 18:0	C 18:1	C 18:2	Frying oil*
A 1	Surface	6.2	1.6	64.5	25.3	Soybean / Sunflower
	Internal	6.4	1.5	68.9	22.3	
A 2	Surface	6.8	2.0	64.1	25.2	Vegetable oil
	Internal	5.8	1.9	66.5	22.9	
A 3	Surface	12.5	2.3	60.6	23.2	Palm olein
	Internal	7.7	2.4	66.8	21.8	
A 4	Surface	7.6	1.7	64.3	22.9	Vegetable oil
	Internal	6.1	1.8	69.6	19.0	
A 5	Surface	11.4	1.9	61.2	24.9	Palm olein
	Internal	6.7	2.0	67.6	28.1	
A 6	Surface	8.5	1.6	70.3	16.2	Vegetable oil
	Internal	6.7	1.9	71.1	17.1	

* Declared on the product label.

surface and internal fractions of the almonds and cashew nuts, which was consistent with decreased OSI values in the total oil.

The peanuts (P1, P2 and P3) and sunflower seeds (S1) stored samples showed clear rancid odor when opening the product package, which is consistent with the high PV found in the external oil fraction and, with the exception of sample P3, with the marked increase in polymers indicating advanced oxidation. In this respect, a significant

Table 6
Major fatty acids (%) in surface and internal oils from commercial fried peanuts

SAMPLE	Oil Fraction	C 16:0	C 18:0	C 18:1	C 18:2	Frying oil*
P 1	Surface	13.2	3.3	37.4	40.4	Soybean / Sunflower
	Internal	11.6	3.5	44.0	34.9	
P 2	Surface	12.6	4.2	36.1	41.0	Vegetable oil
	Internal	11.3	4.3	42.1	36.6	
P 3	Surface	11.2	3.6	42.3	38.4	Vegetable oil
	Internal	10.7	3.7	50.1	32.7	
P 4	Surface	19.2	2.8	45.7	22.3	Palm olein
	Internal	14.7	3.7	41.8	35.2	
P 5	Surface	14.2	2.1	56.6	26.8	Sunflower / Palm
	Internal	11.5	4.1	45.5	35.7	
P 6	Surface	11.1	3.7	37.9	41.2	Vegetable oil
	Internal	12.0	3.6	44.6	34.8	
P 7	Surface	19.6	3.6	40.9	35.3	Palm olein
	Internal	12.5	3.6	44.7	37.0	
P 8	Surface	12.6	3.7	44.9	34.9	Vegetable oil
	Internal	11.5	4.0	44.5	34.3	
P 9	Surface	10.2	2.7	45.4	35.6	Vegetable oil
	Internal	10.6	2.6	51.2	31.1	
P 10	Surface	14.0	4.0	41.4	39.4	Sunflower / Palm
	Internal	12.9	3.7	43.8	35.1	

* Declared on the product label.

Table 7
Major fatty acids (%) in surface and internal oils from commercial fried sunflower seeds (S) and cashew nuts (C)

SAMPLE	Oil Fraction	C 16:0	C 18:0	C 18:1	C 18:2	Frying oil*
S 1	Surface	8.7	3.8	24.6	61.4	Vegetable oil
	Internal	6.5	4.0	25.7	61.6	
S 2	Surface	6.4	3.2	34.5	49.8	Vegetable oil
	Internal	5.9	3.1	38.8	46.7	
S 3	Surface	13.3	4.6	24.1	58.4	Vegetable oil
	Internal	10.2	4.4	22.7	61.6	
S 4	Surface	20.1	4.2	32.4	41.7	Palm olein
	Internal	8.5	4.2	29.2	56.1	
C 1	Surface	14.6	2.1	51.5	23.7	Sunflower / Palm
	Internal	11.4	2.1	58.5	20.6	
C 2	Surface	8.8	6.4	55.7	24.4	Vegetable oil
	Internal	10.3	3.5	61.3	18.8	

* Declared on the product label.

Table 8
Oxidative changes in surface and internal oils from selected samples of almonds (A), peanuts (P), sunflower seeds (S) and cashew nuts (C) after 1 year storage

SAMPLE	Oil Fraction	PV (meq/kg of oil)		Polymers (wt % on oil)		OSI (h)	
		Initial	After 1 year	Initial	After 1 year	Initial	After 1 year
A 1	Surface	5.6	63.5	0.2	0.4	18.5	13.2
	Internal	2.9	39.1	0.0	0.0		
A 2	Surface	15.1	47.1	0.3	0.5	16.4	15.0
	Internal	7.7	25.2	0.0	0.0		
P 1	Surface	22.2	226	0.7	4.3	11.2	1.5
	Internal	10.6	138	0.0	1.9		
P 2	Surface	39.8	304	0.8	6.7	2.7	< 1
	Internal	27.6	182	0.0	1.9		
P 3	Surface	38.0	117	1.3	1.3	6.4	4.5
	Internal	18.3	47	0.2	0.6		
S 1	Surface	55.4	540	1.3	13.1	2.2	< 1
	Internal	34.2	220	0.4	10.2		
C 1	Surface	3.3	8.2	0.4	0.3	> 45	28.5
	Internal	1.8	4.5	0.0	0.0		

increase in polymers at ambient temperatures has proved to be an excellent marker of the onset of accelerated oxidation in oils (Martín-Polvillo et al., 2004). Also, an important decrease in the OSI value was observed in the total oil of peanuts and sunflower seeds. Interestingly, although sample P3 showed clear rancid odor when opening the package, its flavor in the mouth was acceptable, indicating that the external and internal lipid fractions presented very different oxidation status. In fact, the PV and polymer contents were substantially higher in the surface oil, indicating a faster development of oxidation in the fraction more exposed to air during storage. In the case of sample P3, the oxidation in the external oil was sufficient to release volatiles responsible for objectionable odor to the headspace of the package, but not enough to produce rancid flavor in the mouth of the tasters. In fact, although PV was high, no polymerization was observed in the surface fraction of the stored samples. The volatiles concentrated in the headspace were therefore lost when opening the package and did not contribute to mouth perception. The results obtained in sample P3 were just the opposite of those commented above for sample P8, which illustrates the complexity of oxidation in these products. The lower resistance to oxidation of peanuts and sunflower seeds at ambient temperature was in agreement with the results of the accelerated test (OSI) obtained in the total oil of the initial samples (Table 8).

Starting from the raw nuts it is possible to know the changes during frying and the contribution of the frying oil to the lipids in the final product. Thus, the product composition and fatty acid composition in almonds, peanuts and sunflower seeds fried in palm olein were compared to those of the raw nuts.

Table 9 shows the changes in product composition as a consequence of frying. As expected, the loss of moisture and the oil gain were significant in the three samples. In the case of the almonds and peanuts, the loss of moisture was compensated by the oil gain and there was therefore no difference in the dry lipid-free matter percentage. However, in the sunflower seeds a larger increase of oil weight in relation to the moisture loss, possibly due to a higher surface-to-weight ratio, caused a decrease in the dry lipid-free matter percentage.

Table 10 shows the fatty acid composition of the total, surface and internal oil fractions extracted from the fried samples, as well as the fatty acid composition of the frying fat. As expected, the fatty acid composition of the internal lipids was very similar to that found for the raw products (data not shown). On the contrary, the influence of the palm olein used for frying on fatty acid composition was evident in the surface oil. Given the difference in fatty acid composition between the frying fat and the nuts, the percentage of frying oil in the oil surface can be mathematically calculated (Pérez-Camino et al, 1991). From the content of palmitic acid in the raw products and in the palm olein, the estimated proportion of frying oil in the surface oil was 23%, 24% and 40% for almonds, peanuts and sunflower seeds, respectively. Therefore, although substantial contents of frying fat are present, the

Table 9
Composition of almonds, peanuts and sunflower seeds fried in palm olein

ANALYTICAL		ALMONDS		PEANUTS		SUNFLOWER SEEDS	
		Raw	Fried	Raw	Fried	Raw	Fried
Moisture (wt % on nut)		4.5	1.3	3.6	2.4	5.1	0.6
Oil (wt % on nut)	**Total**	45.5	47.5	43.8	46.4	37.7	46.7
	Surface	1.2	3.3	2.2	5.0	1.3	8.3
	Internal	44.5	44.7	40.8	41.2	35.9	38.7
Dry lipid-free matter (wt % on nut)		50.0	51.2	52.6	51.2	57.2	52.7

Table 10
Fatty acid composition (%) of total, surface and internal oil from nuts fried in palm olein

FATTY ACIDS	PALM OLEIN	ALMONDS			PEANUTS			SUNFLOWER SEED		
		total	surface	internal	total	surface	internal	total	surface	internal
C16:0	38.2	8.4	14.9	8.0	13.0	19.1	13.3	10.5	20.0	8.5
C16:1	0.2	0.5	0.6	0.6	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
C18:0	3.9	1.5	2.1	1.7	3.9	4.0	4.0	4.4	4.2	4.2
C18:1	41.5	62.6	58.1	65.2	40.3	37.3	41.2	32.0	32.3	29.3
C18:2	11.1	25.8	21.8	23.6	35.1	31.5	35.4	53.3	42.7	56.1
Others	5.1	0.3	2.7	1.1	7.7	8.2	6.5	0.0	0.8	1.9

surface oil of the intact fried nuts mainly comprised the nut lipids.

The lipid distribution in fried nuts makes it complex to evaluate the oxidative quality from an analysis of total lipids. Samples with no objectionable odor presented clear rancidity in the mouth of the tasters, and the opposite was also detected throughout this investigation. The independent analysis of the external and internal lipid fractions may be useful for a better understanding of the oxidative quality of fried nuts. The results of this study have shown the occurrence of two lipid fractions with different oxidation levels. Higher oxidation levels were normally found in the oil fractions more exposed to air, although considerably higher oxidation status in the internal oil was also detected in various samples. The composition of the surface oil can be changed by the incorporation of substantial contents of the frying fat. Consequently, the frying fat may exert some effect on the oxidative quality and stability of the surface oil.

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