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Characterization of almond kernel oils of five almonds varieties cultivated in Eastern Morocco

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Abstract. This study focuses on characterization of almond kernel oils extracted mechanically from five sweet almond varieties: 'Marcona', 'Fournat', 'Ferragnes', 'Ferraduel' and 'Beldi'), cultivated in eastern Morocco. Oil content, physicochemical parameters, triacylglycerol and fatty acid compositions were determined. Analyzed oils showed low acidity values that range between 0.77-0.88%, peroxide values range between 6.43-16.39 meq/kg and Iodine values range between 98.42-103.90%. The principal fatty acid of almond kernel oils is oleic acid (C18:1); oils of 'Ferragnes-Ferraduel' and 'Beldi' varieties show higher values of C18:1 respectively of 72.87 and 71.62%, however 'Fournat' almond kernel oil shows the lowest content of C18:1 (63.54%). HPLC analysis of triglycerides was carried out, and results show that analyzed almond kernel oils are characterized by the dominance of trioleylglycerol (OOO) that contents range between a minimum of 31.48% for Fournat's oil and 43.82% for Ferragnes-Ferraduel's oil. The oxidative stability of almond kernel oils was determined by rancimat tests as the induction period (IP, h recorded by a 743 Rancimat apparatus Metrohm, Switzerland). Results show that stability, of almond kernel oils is clearly influenced by the almond variety; Oxidative stability of tested almond kernel oils ranged between an IP = 20.28 h for 'Marcona' oil and an IP = 27.55 h for 'Ferragnes-Ferraduel'.

Keywords. Almond kernel oil – Fatty acid – Triglycerides – Oxidative stability.

Caractérisation des huiles de cinq variétés amandes cultivées au Maroc oriental

Résumé. Cette étude porte sur la caractérisation physico-chimique d'huiles de 5 variétés d'amande douce ('Marcoma', 'Fournat', 'Ferragnes', 'Ferraduel' et 'Beldi'), cultivées dans la région orientale du Maroc. Les huiles d'amandes sont extraites mécaniquement, le rendement en huile, les paramètres de qualité (les indices d'acidité, de peroxyde, d'iode et l'absorbance en UV) ont été déterminés, et également la composition en acide gras et le profil de triglycérides, ont été analysés. L'huile extraite possède un faible indice d'acidité qui s'oscille entre 0,77-0,88% d'acide Oleic, l'indice de peroxyde varie entre 6,43-16,39 meq/kg et l'indice d'iode varie entre 98,42-103,90% I₂. Les profils d'acides gras des huiles d'amandes analysées montrent une dominance de l'acide oléique (C18:1) dont les teneurs varient respectivement entre une teneur minimale de 63,54% pour 'Fournat' et un maximum de 72,87% pour le mélange 'Ferragnes-Ferraduel'. L'analyse des triglycérides a été réalisée par HPLC et se caractérise par la dominance de trioleylglycerol (OOO) dont les teneurs varient entre un minimum de 31,48% et un maximum de 43,82% respectivement pour 'Fournat' et le couple 'Ferragnes-Ferraduel'. Les résultats de test Rancimat pour l'analyse de stabilité oxydative des huiles d'amandes étudiées montrent que ces huiles sont relativement stables avec des temps d'induction qui varient entre 20,28 h et 27,55 h.

Mots-clés. Huile d'amande – Acide gras – Triglycérides – Stabilité oxydative.

I – Introduction

The almond tree (*Prunus amygdalus L.*), is considered as a drought tolerant crop, its ability to endure high water deficits is related to its efficiency in valorizing marginal soils. In Morocco, cultivation of almond tree constitutes the second most important plantation of fruit trees after olive growing; it is mostly cultivated in two regions, « Taza-Al Houceima-Taounate » in the north and « Souss-Massa Draa » in the south. In Eastern Morocco plantations of almond trees cover 9% and produce 14% of Moroccan production of almond kernels (MAPM, 2014). According to (Giove and Abis, 2007), (FAOStat, 2012) and the Moroccan Agriculture Ministry's Report (MAPM, 2014), Morocco is generally classified as the sixth producer in the world. Many times, sweet almonds are simply eaten raw or toasted. However, there are numerous uses of almonds as an ingredient in manufactured food products or to extract odorless edible oil that's largely used in cosmetic for external applications for the skin and hair. Thus this study aims to characterize sweet almond oils extracted mechanically from five most important varieties ('Marcona', 'Fournat', 'Ferragnes', 'Ferraduel' and 'Beldi') cultivated in Eastern Morocco.

II – Materials and methods

Samples of sweet almonds (Crop year 2013) of five varieties ('Marcona' (Mr), 'Fournat' (Fn), 'Ferragnes-Ferraduel' mixture (F/F) and 'Beldi' (Be)) were provided from a cooperative of almond producers "AMANDES-SidiBouhria" located nearby Oujda in eastern region of Morocco. The extraction of almond oil (AO), by screw press was realized in a company of seed oils (PRODIGIA, Casablanca). Pressing was carried out at room temperature with a Komet screw press (model DD85G, Germany), with a 5mm restriction die and a screw speed of 20 RPM. Oils were conserved at 4°C.

Free acidity, peroxide values and UV absorption indices (K_{232} , K_{270}) were determined according to commercial standard methods for olive oil (IOOC, 2001).

Fatty acid (FA) composition: FAs were converted to FA methyl esters and were analyzed by a HP 5880 A series GC System chromatograph, equipped with a capillary column (25 m x 0.25 mm x 0.26 μ m) and a FID detector. The carrier gas was nitrogen, at a flow of 1.7 ml/min. the temperatures of the injector and detector were set at 150 and 250°C respectively and the oven temperature was set at 250°C. The injection volume was 1 μ l.

Iodine values (I_2N) were calculated from fatty acid percentages (Torres and Maestri, 2006, Maestri *et al.*, 2014) by using the following formula:

$$I_2N = (\% \text{ Palmitoleic acid} \times 1,001) + (\% \text{ oleic acid} \times 0,899) + (\% \text{ linoleic acid} \times 1,814).$$

Triacylglycerol (TAG) analysis was determined by HPLC system. The mobile phase consisted of acetone/acetonitrile (60/40; V/V). HPLC analyses were conducted using C18 reversed-phase column (ODS C18: 250 x 5 mm, 5 μ m). Almond oils were dissolved in acetone (9%) and filtered through 0.45 μ m membranes. The injection volume is 20 μ l.

Oxidative stability indices (OSI) of AO were evaluated by Rancimat test (Rancimat model 743, Metrohm, Switzerland) with an air flow rate of 15L/h and temperature of the heating block maintained at 100°C, OSI of oils was reported as their equivalent induction times (h).

III – Results and discussion

1. Oil Content and oils analysis

The oil content from studied almond varieties (Table 1) varies from 48.62% for 'Fournat' to a maximum of 61.62% for 'Marcona' and they are comparable to that reported previously by other authors (Kornsteiner *et al.*, 2006, Kodad and Socias i Company, 2008, Moayed *et al.*, 2011, Martínez *et al.*, 2013,

Maestri *et al.*, 2014). Acid values (AV) ranged from 0.077 to 0.088 mg KOH/g oil and are much lower than the maximum values established for non-refined vegetable oils (Commission of Codex Alimentarius, 2009). High peroxide values (PV) were recorded only for AO's from 'Marcona' and 'Beldi' but, high iodine values (I_2V) were observed for all analyzed AOs (Table 1), indicating that AOs studied here are highly unsaturated and therefore susceptible to oxidative degradation. In relation to this and according to varieties, significant differences were found ($p < 0.05$) for PV and UV values.

Table 1. Oil contents and physicochemical characteristics of analyzed almond oils

Parameters	Almond varieties			
	Mr	Fn	F/F	Be
Oil (%) [†]	61.62 ± 1.4	48.62 ± 2.1	58.99 ± 1.1	61.00 ± 1.7
AV	0.81 ± 0.008	0.88 ± 0.005	0.88 ± 0.004	0.77 ± 0.009
PV	14.32 ± 0.41	6.43 ± 2.73	8.13 ± 2.81	16.39 ± 2.95
K ₂₃₂	1.54 ± 0.2a	3.53 ± 0.11c	1.33 ± 0.14a	2.29 ± 0.03b
K ₂₇₀	0.073 ± 0.004 ab	0.129 ± 0.005c	0.053 ± 0.006a	0.088 ± 0.003b
I_2N	102.25 ± 0.13	103.90 ± 0.16	98.42 ± 0.11	98.97 ± 0.25
OSI (h)	20.28 ± 0.45a	21.22 ± 3.31a	27.55 ± 0.714b	23.5 ± 0.62a

[†] Oil content (%dry basis), AV acid value (mg KOH/g oil), PV peroxide value (meq.O₂/kg oil), IV iodine value (g I_2 /g oil), OSI: Oxidative Stability (Induction time, h)Significant differences in the same row are shown by different letters (a-c) varieties ($p < 0.05$).

2. Fatty acid and Triacylglycerol compositions

Fatty acid (FA) and Triacylglycerol (TAG) compositions of oils of the studied almond species are presented in Table 2 and Fig. 1 respectively. Low contents of saturated fatty acids and high contents of monounsaturated oleic acid are highly favorable for human nutrition. For examined AOs the main FAs are oleic, linoleic and palmitic acids and fatty acid compositions shown a typical characteristic of a low concentration of SFAs (SSFA, 8-10%), intermediate for PUFAs (SPUFA, 17-25%), and high for MUFAs (SMUFA, 64-73%). Similarities between the studied AOs permit to class them in two categories (Fn, Mr); and (B, F/F). According to I_2N and OSI (Table 1), AOs of Be& F/F shown the best stability.

Table 2. Fatty acid compositions (%) of analyzed almond oils

Fatty acid %	Almond varieties			
	Mr	Fn	F/F	Be
Palmitic (C16:0)	7.15 ± 0.14c	7.91 ± 0.05d	6.53 ± 0.12a	6.79 ± 0.09b
Palmitoleic (C16:1)	0.70 ± 0.03c	0.61 ± 0.01b	0.55 ± 0.02a	0.59 ± 0.02b
Margaric (C17:0)	0.102 ± 0.002	0.101 ± 0.001	0.104 ± 0.003	0.100 ± 0.002
Stearic (C18:0)	2.20 ± 0.05b	2.15 ± 0.04b	2.01 ± 0.04a	1.98 ± 0.09a
Oleic (C18:1)	66.87 ± 0.66b	63.54 ± 0.32a	72.87 ± 0.42d	71.62 ± 0.45c
Linoleic (C18:2)	22.84 ± 0.38c	25.45 ± 0.31d	17.84 ± 0.38a	18.74 ± 0.34b
Oleic / Linoleic (O/L)	2.92 ± 0.007	2.49 ± 0.006	4.082 ± 0.005	3.82 ± 0.002
SSFA	9.35 ± 0.09c	10.06 ± 0.01d	8.54 ± 0.09a	8.78 ± 0.10b
SMUFA	67.56 ± 0.64b	64.15 ± 0.31a	73.42 ± 0.41d	72.21 ± 0.43c
SPUFA	22.84 ± 0.38c	25.453 ± 0.31d	17.843 ± 0.38a	18.737 ± 0.34b

'Marcona' (Mr), 'Fournat' (Fn), 'Ferragnes / Ferraduel' mixture (F/F), 'Beldi' (Be) Values are means of four different almond oil samples ($n = 3$) ± SD (standard deviation) Significant differences ($p < 0.05$) in the same row are shown by different letters (a-d). SSFA: Sum of saturated fatty acids; SMUFA: Sum of mono-unsaturated fatty acids; SPUFA: Sum of polyunsaturated FA.

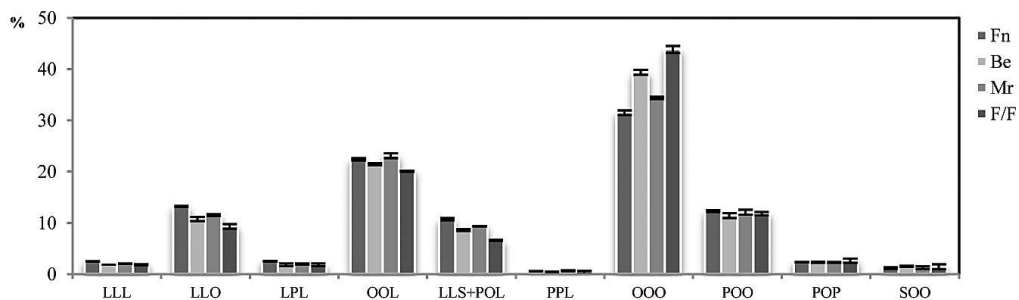


Fig. 1. Triacylglycerol composition of almond oils analyzed by HPLC, TAGs are abbreviated using L, O, P, S respectively for Linoleoyl, Oleoyl, Palmitoyl, and Stearoyl FA radicals.

TAG profiles (Fig. 1) show that contents of TAGs in analyzed AOs, decrease in the following order: OOO > OOL > POO > LLO > POL + LLS > LLL > LPL > POP > SOO > PPL. Two predominant TAGs are OOO (31-44%) and OOL (20-23%) which altogether represent more than 50% of the total TAGs, they are followed by POO and LLO, with quantities around 10%. Significant differences are found when analyzed oils are compared pairwise and particularly for their contents in OOO, OOL, and LLO.

IV – Conclusion

Oil content, FA composition, TAG profile and the physicochemical characteristics of sweet AOs of five varieties cultivated in eastern Morocco were studied for the first time. Significant variations have been observed in FA among studied varieties and similarities between the studied AOs permit to class them in two groups (Fn, Mr); and (Be, F / F). Oils, of group “Be, F / F”, are distinguished by their richness in C18:1 and low content of C18:2, which confer them a better oxidative stability, and therefore they could be recommended as varieties for planting program in the eastern region of Morocco.

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