Region and watering frequency effects on quality and acid composition evolution of Moroccan olive oil (*var. Moroccan Picholine*)

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Abstract

The study on the evolution of some quality parameters and acid composition of olive oil from the Moroccan variety Picholine marocaine has yielded very interesting results concerning orchards in different areas and under two types of irrigation.
The maturity index has shown a notable variation among orchards. High maturity rates (between 4.50 and 4.80) are observed for non-irrigated systems on November 20th .
The weight of fruits varies depending on three factors: fruit maturity, charge of trees and irrigation system.
Concerning the water and oil content evolution, noticed that in the irrigated orchards these parameters present two distinct phases. The first between September 19th and November 20th , during which water contents are constant, whereas the oil content increases permanently. The second phase begins on November 20th , and the two parameters exhibit an inverse evolution, with an increase in the oil content.
The total fatty acid evolution has allowed discriminating among orchards under different irrigation systems. This has been possible by comparing the time of the shift from the palmitic acid (before olive ripeness) to the linoleic acid predominance (during olive ripeness). Indeed, this time is relatively fast for non-irrigated orchards.
In the same place of production, the linolenic acid proportions are moderately lower in non-irrigated orchards than in the irrigated ones. The levels of this fatty acid (normally exceeding 1% for the Picholine marocaine) are affected by the fruit maturity and by the irrigation system.
Finally, the economic impact of the present study is also discussed.

Résumé

L'étude de l'évolution de certains paramètres de qualité et de la composition acidique de l'huile d'olive chez la Picholine marocaine a permis d'obtenir des résultats intéressants sous l'effet de la région et du système d'irrigation.
En fonction du système d'irrigation, l'indice de maturité a montré une nette variation, les valeurs les plus élevées (entre 4,50 à 4,80) ayant été observées dans les vergers non irrigués vers le 20 novembre.
La variation du poids des fruits dépend de trois facteurs: la maturité des fruits, la charge des arbres et le système d'irrigation.
En ce qui concerne l'évolution des teneurs en eau et en huile, nous notons que, dans les vergers irrigués, ces deux paramètres présentent deux phases distinctes. La première se situe entre le 19 septembre et le 20 novembre, durant laquelle les teneurs en eau sont pratiquement constantes. Cependant, les teneurs en huile montrent une augmentation continuelle. Dans la seconde phase, entre le 20 novembre et le 3 janvier, les deux paramètres affichent plutôt une évolution inverse, avec une tendance vers l'augmentation des teneurs en huile.
L'évolution des acides gras totaux nous permet de distinguer entre les vergers provenant de différents systèmes d'irrigations en comparant le temps nécessaire pour passer de la dominance palmitique (avant la maturité des olives) à la dominance linoléique (au stade de maturité des olives). En effet, ce passage est relativement rapide dans les vergers non irrigués.En considérant la même localité, les teneurs en acide linolénique sont légèrement inférieures dans les vergers non irrigués. Les teneurs en acide gras (normalement supérieures à 1% chez la Picholine marocaine) sont influencées par la maturité des fruits et par le système d'irrigation.
L'impact économique de cette étude est également évoqué.

1. Introduction

In Morocco, the olive production is restricted to two olive-growing areas (Anonyme, 1996). The first in the north, where olive groves are only rain-fed. The second in the south, where irrigation is necessary for the growth of olive trees. It is noteworthy to notice that the quality of olive oil is not only a function of the variety (Cimato, 1990; Inglese, 1994), maturity (Maestro and Borjas, 1990) and climatic conditions (Mazliak, 1968), but also of cultural techniques (carried out during the different stages of the production cycle) (Dettori and Russo, 1993; Bruni et al., 1994). Thus, in the south area, irrigation is used into two distinct ways according to the economic situation of the farmers (Anonymous, 1995):

- For the rich farmers, irrigation is practiced several times during the year, especially by pumping water.
- For the poor ones, irrigation is occasionally provided by floods.

Accordingly, it seemed very interesting to choose this area, in order to investigate the influence of irrigation frequency on the lipid composition and biometric parameters of the Picholine marocaine variety in Morocco.

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2. Material and Methods

2.1 Material

Sampling

Olive sampling is carried out in the olive-growing area in South Morocco. Adult olive trees of Picholine marocaine are used. Olives are picked up manually and the oil extracted on the same day in the laboratory using the machine called "Oléodoseur".

Studied fields

Sampling fields are located in three areas of the olive-growing zone in South Morocco. When it is possible, two different orchards are selected in each area:

** an irrigated one where olive trees are regularly watered every fortnight;

** a non-irrigated one where watering is carried out only by occasional floods.

Areas and locations

Three representative growing areas were selected, where eight locations were chosen according to Table1. In the EL Kalâa growing area, the two kinds of irrigation system could not been found.

Table 1. *Sampling areas*

Areas	Locations	Irrigation systems	Codes
Sâada	Menara	Irrigated	M(I)
	Nfis	Irrigated	Nf(I)
	Tamzgelft	Non-irrigated	Tm(NI)
Ait Ourir	Ait ourir	Irrigated	A(I)
	Ait ourir	Non-irrigated	A(NI)
El Kalâa	Tassaout	Irrigated	Ta (I)
	El Attaouia	Irrigated	E(I)
	El Kalâa	Irrigated	K(I)

Sampling was carried out on nine mature plants of similar age and production in each area. Apart from irrigation frequency, all the other agronomic techniques in the studied zones are roughly identical for all the farmers.

Sampling period

The sampling period started from September until January. Seven samples from each orchard were collected according to the following calendar (Table 2).

2.2 Methods

Extraction method

The oil was obtained using an "Oléodoseur" machine after the following three steps:

• Grinding: olives were crushed with a hammer crusher.

• Mixing: the resulting paste was then mixed at 1400 g for 30 min. Mixing

was performed in two steps: the first without water in 20 min and then adding 100 ml of boiling water before a subsequent mixing for 10 min.

• Centrifugation: the resulting mixture was centrifuged at 2845 g for 1 min.

Sampling characterization

Hundred olives were randomly chosen for maturity index (Uceda and Frias, 1975) which was calculated after a visual color appreciation using the formula below.

IM = (ax0) + (bx1) + (cx2) + ... + (hx7) / 100

With 0 £ IM £ 7

a, b, ... ,h are the number of fruits having the same color. Eight color classes were considered (0, 1, 2, ... , 7), varying from dark green (0) to dark black (7).

Olives and weights of their kernels were determined for the same hundred fruits randomly chosen using an analytical balance.

Table 3. *Maturity index evolution*

	Dates of sampling						
	19 / 9	17 / 10	1 / 11	20 / 11	4 / 12*	19 / 12	3 / 1
M(I)	0.6	1.4	1.9	2.1	1.8	1.9	2.1
Ta(I)	0.5	1.5	1.9	2.5	2.4	2.6	2.6
K(I)	1.1	2.3	2.4	2.8	2.8	3.1	2.7
E(I)	0.7	1.4	2.2	2.8	2.9	2.9	3.7
A(I)	1.1	2.3	3.1	4.1	3.4	--	–
A(NI)	1.5	3.1	3.5	4.8	4.2	--	–
Nf(I)	0.6	1.1	1.9	2.5	3.3	2.8	3.0
Tm(NI)	1.1	2.6	3.4	4.5	4.0	--	–

* 4/12 : date of the last harvest in A(I), A(NI) and Tm(NI)

Oil analysis

Moisture, oil content by NMR and free fatty acids were determined according to the AFNOR methods T60-201, NFV 03-907 and T60-204 respectively. Total fatty acid analysis was performed after the preparation of the corresponding methyl esters according to the AFNOR method T60-233, with a Delsi series 30 gas chromatograph on a Carbowax 20M capillary column (30m x 0.25 mm ID). Flame ionization was used for detector. The chromatographic conditions were as follows: injector 200°C, detector 210°C and column oven 170°C.

Table 2. *Sampling period*

Sampling number	Sampling dates
1	September 19th
2	October 17th
3	November 1st
4	November 20th
5	December 4th
6	December 19th
7	January 3rd

Statistic determinations

The SAS software was used for the processing of parameters. Initial analysis was performed by "MGLM" method, before a subsequent total processing using multivariate analysis "MANOVA".

3. Results and discussions

3.1 Evolution of the maturity index

Data displayed in Table 3 show that the maturity index of the orchards has a slightly identical evolution: a permanent increase from September 19th to November 20th, followed by a stagnating period in which the maturity index reached its maximum. A similar behavior, with higher values (a maximum value of 4.8 was reached in January 16th) was observed in the previous study carried out in the Marrakech region (Ajana et al., 1999). However the values recorded were higher in non-irrigated orchards (4.0 - 4.8) than in the irrigated ones (2.5 - 3.5).

According to the statistical data, in the orchards with the same irrigation system, the maturity index values were close enough even though each orchard kept its own rate.

It is also clear that orchard A(I) had a maturity evolution faster than the other irrigated orchards (from 1.1 on September 19th, to 4.1 on November 20th). This might be attributed to the low production of trees in this orchard.
Based on these facts, we can state that the maturity index depends on the harvest time. In addition, the maximum value reached is also influenced by the intrinsic and extrinsic conditions of trees such as production, trimming, irrigation frequency ...etc.

3.2 Fruit and kernel weight

Weights of kernels were between 0.40 and 0.78 g (Table 4). However, no remarkable variation was observed in any of the orchards in all the sampling period. This is probably due to the fact that kernels had already reached their final dimension before our first sampling (September 19th). This result is corroborated by our previous study which showed that endocarp hardness of the Picholine marocaine is achieved in July (Ajana et al., 1999). After this month, the rise in the fruit weight was only due to the mesocarp development.

As for the fruit weight, in the Ait Ourir area, values were higher for olives from irrigated orchard (4.29 g average) than those from the non-irrigated ones (3.34 g on average). A stabilization of the fruit weight was also observed since November 1st in "A(I)", while it increased in "A(NI)". However, the Saâda area showed an opposite behaviour: higher fruit weight values (4.52 g on average) in non-irrigated orchard "Tm(NI)" with a stagnation period from November 1st and relatively low values (3.20 g on average) in the irrigated orchard "Nf(I)" with an increase in the fruit weight during the same period. This would be attributed to the tree production. Indeed, a low production makes nutrition competition less important, resulting in an increase in the fruit weight. However, another parameter, which is the tree maintenance (trimming), could be involved. Thus, even though production is low, the fruit might be light for the lack of trimming (as it was the case of "A(NI)").

3.3 Evolution of water and oil content

From a statistical study of water and oil content evolution, we have concluded that these two parameters have shown a very highly significant correlation.

In the non-irrigated orchards, an opposite behavior was reckoned for these two parameters: when one increases the other decreases. Meanwhile, in irrigated orchards, this tendency is less important, because the water content remained nearly constant afterwards the first sampling (Table 5). This can be explained by the competition between water and oil for the occupation of the cell space (Mazliak, 1968).

The oil content gained between September 19th and November 20th was higher in the non-irrigated orchard "Tm (NI)" compared to the irrigated one "Nf (I)". Moreover, the oil content evolution showed a stability in "Tm (NI)" from October 17th , while in "Nf(I)", a continuous and slow increase was observed from September 19th to November 20th , before a increase between November 20th and January 3rd up to 45% during the last sampling.

Unlike the Saâda area, the oil content evolution and values in the Ait Ourir area were similar in both irrigated and non-irrigated orchards during the sampling period.

The water content was generally higher in non-irrigated orchards and presented an increase evolution during the sampling period.

Table 4 : *Fruit and kernel weight evolution (g)*

Locations	Parameters	Dates of sampling 19 / 9	17 / 10	1 / 11	20 / 11	4 / 12	19 / 12	3 / 1
M(I)	Wf*	2.40	3.00	3.00	3.10	3.20	3.10	3.15
	Wk*	0.54	0.57	0.52	0.50	0.50	0.50	0.52
Ta(I)	Wf	2.95	3.20	3.50	3.90	3.80	3.70	3.50
	Wk	0.60	0.60	0.63	0.56	0.62	0.56	0.58
K(I)	Wf	3.50	4.60	4.50	4.40	4.80	4.10	4.40
	Wk	0.66	0.73	0.70	0.65	0.67	0.54	0.65
E(I)	Wf	2.70	3.40	3.90	3.60	3.70	4.40	4.00
	Wk	0.60	0.60	0.60	0.40	0.60	0.60	0.60
A(I)	Wf	3.40	4.50	4.60	4.50	4.50	-	-
	Wk	0.73	0.73	0.74	0.72	0.78	-	-
A(NI)	Wf	2.10	3.80	3.30	3.60	3.90	-	-
	Wk	0.70	0.70	0.50	0.70	0.70	-	-
Nf(I)	Wf	2.30	2.90	3.10	3.00	3.50	3.50	4.10
	Wk	0.50	0.50	0,45	0.50	0.50	0.50	0.50
Tm(NI)	Wf	3.90	4.40	4.90	4.70	4.70	-	-
	Wk	0.71	0.68	0.66	0,66	0.68	-	-

*Wf = Weight of the fruit
Wk = Weight of the kernel

Table 5. *Water and oil content evolution (%)*

Dates of sampling													
19/9		17/10		1/11		20/11		4/12		19/12		3/1	
W*	O*	W	O	W	O	W	O	W	O	W	O	W	O
59.40	22.30	37.20	39.82	37.35	39.16	38.10	37.34	40.40	42.53	41.60	37.03	40.00	39.96
63.70	20.68	36.90	30.55	39.60	36.30	39.80	36.83	42.00	41.74	47.20	38.90	40.20	43.71
61.20	28.23	38.70	34.03	41.50	33.44	38.60	36.32	43.90	46.30	44.00	31.30	37.50	43.27
58.80	24.27	41.80	34.84	45.50	34.10	46.80	33.53	43.40	40.50	43.30	34.23	45.10	45.20
59.00	23.13	37.60	31.60	43.70	35.85	46.30	34.74	44.70	34.92	-	--	-	-
46.40	22.27	40.30	31.74	39.90	37.57	56.00	32.14	47.30	40.30	-	--	-	-
60.60	25.24	39.30	33.47	40.20	35.42	44.60	34.72	45.50	41.64	43.20	40.65	37.90	45.16
64.30	29.58	43.80	38.20	45.20	39.21	51.70	36.80	53.00	37.64	-	--	-	-

*: W: water content; O: oil content

3.4 Free fatty acid content evolution

Acidity levels proved to be almost similar for all the studied orchards and rarely exceeded 0.50% (Table 6). Thus, it can be stated that the extracted oil was extra virgin. This was in full accordance with our previous results (Ajana et al., 1998) showing that when olives are immediately processed, the acidity levels are always below 0.50%. Furthermore, it confirms that the Picholine marocaine, besides the other Mediterranean varieties (Cimato, 1990; Stefanoudaki and Koutsaftakis 1995), allows to produce extra virgin oil. It is noteworthy to emphasize that the irrigation system has no effect on free fatty acid contents in oil; this result is corroborated by the conclusions of Dettori and Russo (1993).

In fact, only the state of fruits at extraction could have a direct influence on the acidity level (Cavusoglu and Oktar, 1994; Boschelle et al., 1994). It is the case of the Ait Ourir area where the attacks by the olive fly (Bactrocera oleae) has caused the increase of acidity during sampling from November 20th to December 4th .

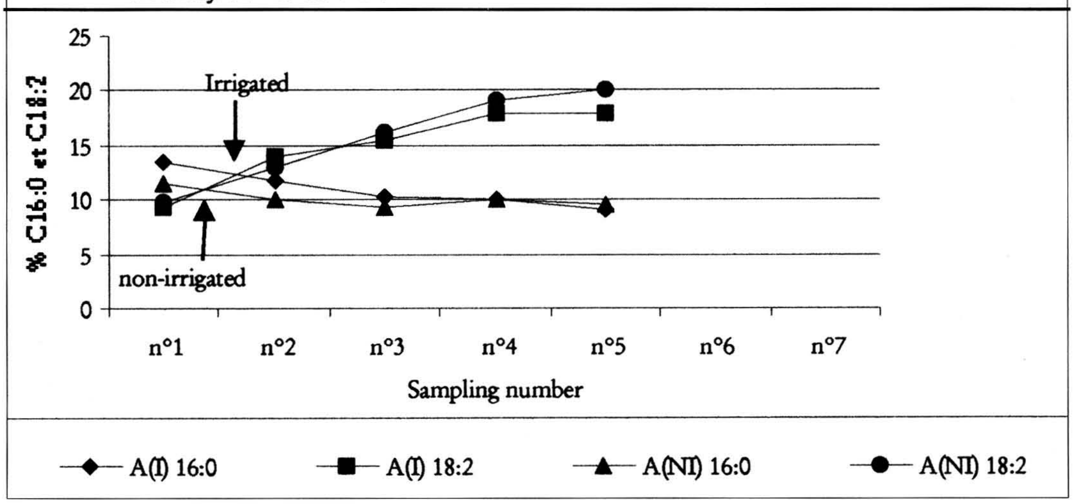
Table 6. *Evolution of acidity (% of oleic acid)*

Locations	Dates of sampling						
	19 / 9	17 / 10	1 / 11	20 / 11	4 / 12	19 / 12	3 / 1
M(I)	0.39	0.38	0.33	0.48	0.65	0.47	0.44
Ta(I)	0.37	0.34	0.34	0.39	0.32	0.38	0.34
K(I)	0.46	0.41	0.35	0.43	0.39	0.39	0.48
E(I	0.36	0.36	0.32	0.32	0.41	0.41	0.48
A(I)	0.31	0.37	0.36	0.75	0.90	-	-
A(NI)	0.33	0.33	0.36	1.35	0.76	-	-
N(I)	0.36	0.35	0.38	0.51	0.40	0.38	0.36
Tm(NI)	0.36	0.30	0.34	0.45	0.40	-	-

3.5 Methyl esters of total fatty acids

The main fatty acids of Picholine marocaine were palmitic, oleic and linoleic. Among these components, oleic acid was predominant ranging from 65 to 75%. A clear inverse correlation between palmitic and linoleic acids was also noted; palmitic acid content decreased while linoleic acid rate increased during the sampling period. In addition, the watering frequency turned out to have an influence on the date of the shift from palmitic acid (before olive ripeness) to linoleic acid predominance (during olive ripeness). Indeed, in the same area this shift is faster in non-irrigated orchard (before October) than in the irrigated one (after October 15th) (Graph 1).

Graph. 1. *Palmitic acid and linoleic acids evolution in irrigated and non-irrigated orchards from Ait Ourir are*



On the other hand, linolenic acid level was found to exceed 0.9% most of the time and showed low values in non-irrigated system compared with the irrigated ones in the same area.

According to the literature, the new I.O.C. norm (I.O.C., 1999) for the total fatty acids is not specific for the Picholine marocaine but it can be also extended to other varieties in many Mediterranean countries. Thus the Blanquita variety (Portugal) showed linolenic acid level above 0.9% (Gouveia, 1997), while several Italian varieties "Leccino, Nociara and Ogliarola salentina" had reached a value as high as 1.2% (Dettori and Rossu, 1993).

As regards other minor fatty acids, their proportions were similar regardless of the irrigation system and the area of cultivation.

4. Economic impact

This study tries to show that under various watering frequencies, Picholine marocaine produces oil with linolenic acid rates generally higher than 1% (new I.O.C. upper limit). Similar rates were recorded for other Mediterranean varieties such as Blanquita (Gouveia, 1997), Leccino, Nociara and Ogliarola salentina (Dettori and Rossu, 1993). Thus, rates a little higher than the current standard values (I.O.C., 1999), could include these varieties in the commercial standard for the virgin olive oils.

It must be noted that, generally, the determination of the commercial standards takes into consideration the quantitative variation of the lipid composition (Anonymous, 2000(b) ; Anonymous, 2001). This variation is affected by several factors: variety, environment, farming techniques, analysis method, sensibility, etc.

Therefore, of paramount importance is that olive producing-countries set up their own complete olive growing range in order to contribute to the establishment of the new Codex Alimentarius standards (Anonymous, 2000(a)).

Furthermore, periodical revision of the virgin olive oil commercial standards in the light of data from the producing countries, would promote a more even trade at world level.

5. Conclusions

The watering frequency has greatly affected the maturity index as we observed high values in non-irrigated orchards. As for the oil and water contents, an inverse behaviour was noted in non-irrigated orchards: when one increased, the other decreased. Meanwhile, this evolution was not observed in irrigated orchards as water content remained roughly stable after the first sampling (September 19th).

Nevertheless, no noticeable effect of irrigation system was observed on the acidity level; the Picholine marocaine oil is an extra virgin one in all the studied orchards during the sampling period. A marked influence of the watering frequency was also highlighted in the period of the shift from palmitic acid to linoleic acid predominance. In addition, the level of linolenic acid showed low values in non-irrigated orchards compared with those recorded in the irrigated ones.

References

Anonymous, (2000). "83e session du Conseil Oléicole International". - Olivae n° 84, pp 5-7.

Anonymous, (2000) (b). "Programme d'activités techniques pour l'année 2000 du COI". Olivae, n° 84, pp. 20-22.

Anonymous, (2001) "84e session du Conseil International". Olivae n° 87, pp. 5-7.

Ajana H., EL Antari A., and Hafidi A. (1998). Fatty acids and sterols evolution during the ripening of olives from the Moroccan Picholine cultivar. Grasas y Aceites Vol. 49 Fasc. 5-6, pp. 405-410.

Ajana H., EL Antari A., and Hafidi A. (1999). Evolution of biometric parameters and chemical composition of olives from Moroccan Picholine variety fruit ripeness. Grasas y Aceites Vol. 50 Fasc.1, pp. 1-6.

Anonymous, (1995). Ministère de l'agriculture et la réforme agraire. L'olivier et sa culture au Maroc : L'olivier dans le périmètre irrigué du Haouz de Marrakech. Olivae n∞ 58, pp. 35.

Anonymous, (1996). Ministère de l'agriculture et la réforme agraire. L'oléiculture marocaine : Situation actuelle et perspectives d'avenir. Le Pôle Alimentaire n∞ 3, pp. 14 - 17.

Atouati, B. Y. (1991). Evolution des caractéristiques carpométriques et de la fraction phénolique totale avec le stade de maturité des olives, variété : Picholine marocaine. Mémoire de 3ème cycle, IAV Hassan II, Rabat.

Boschelle O., Mozzon M. et Giomo A. (1994). Huile d'olive vierge extra typique : Quelles sont ses perspectives en Frioul-Vénétie Julienne ?.-Olivae n∞ 50, pp. 31 - 35.

Bruni U., Cortesi N. et Fiorino P. (1994). Influence des techniques agronomiques, des cultivars et des zones d'origine sur les caractères de l'huile d'olive vierge et les niveaux de certains de ses composants mineurs. Olivae n∞ 53, pp. 28-34.

Cavusoglu A. et Oktar A. (1994). Les effets des facteurs agronomiques et des conditions de stockage avant la mouture sur la qualité de l'huile d'olive.-Olivae n∞ 52, pp. 18-24.

Cimato A. (1990). La qualité de l'huile d'olive vierge et les facteurs agronomiques. Olivae n∞ 31, pp. 20-31.

C. O. I. (1999). Norme commerciale internationale applicable aux huiles d'olives et aux huiles de grignons d'olive. C.O.I/T15/NC n∞ 2/Rév. 9.

Dettori S. et Russo G. (1993).Influence du cultivar et du régime hydrique sur le volume de production et la qualité de l'huile d'olive.Olivae n∞ 49, pp. 36-43.

Gouveia J.M.B. (1997). Etude comparative entre les huiles d'olive des cvs Cobrançosa, Blanqueta, Azeiteira et Picual et celles du cv Galega vulgar, produites dans le nord de l'Alentejo I. Principales caractéristiques chimiques et sensorielles. Olivae n∞66, pp. 34-45.

Inglese P. (1994). L'influence de la variété sur les caractéristiques qualitatives de l'huile d'olive.Olivae n∞ 54, pp. 42-47.

Li-Chan E., (1994). Developments in the detection of adulteration of olive oil. Trends in Food Science and Technology, vol 5, pp. 3-11.

Maestro R., Borjas R. (1990). La calidad del aceite de oliva en relacion con la composicion y maduracion de la aceitune. Grasas y Aceites, 41, pp. 171-178.

Mazliak P. (1968). Le métabolisme des lipides dans les plantes supérieures. Edition Masson and Cie, Paris.

Norme AFNOR, (1984). Recueil des normes françaises des Corps Gras, Graines Oléagineuses et Produits Dérivés. 3ème édition, Ed Afnor, Paris.

Stefanoudaki E., et Koutsaftakis A., (1995). Les caractéristiques qualitatives de l'huile d'olive crétoise. Olivae n∞ 56, pp. 51-53.

Uceda M., and Frias L., (1975). Epoca de recoleccion. Evolucion del contenido graso del fruto y de la composicion y calidad del aceite. II Seminario Oléicola Internacional. Cordoba.