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COMPOSITIONAL CHANGES IN DEVELOPING ALMOND KERNELS IN RELATION TO ROOTSTOCK AND WATER SUPPLY[1]

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SUMMARY

The investigations conducted on almond trees (*Prunus amygdalus*, cv Texas), showed differences due to rootstocks in the rate of oil accumulation but not on oil content at maturity; water supply resulted in an increase of kernel moisture and free fatty acids in the oil. Neither the rootstock nor water supply significantly affected fatty acid composition or the oil spectrophotometric indices.

Keywords: Almonds, Fatty acid, Spectrophotometric indices of oil.

RIASSUNTO

Modificazioni chimiche e fisiche delle mandorle durante l'accrescimento in relazione al portinnesto e all'irrigazione

Attraverso l'analisi di diversi parametri chimici e fisici è stato studiato il processo di maturazione dei frutti di mandorlo (*Prunus amygdalus*, cv Texas) provenienti da piante innestate su mandorlo amaro e su pesco, mantenute in coltura asciutta e irrigua. In relazione al portinnesto sono state osservate apprezzabili differenze sul contenuto in olio, soprattutto nel periodo di maggiore accumulo (luglio-settembre). Tali differenze tendevano però a livellarsi nei campioni di mandorle mature.
L'apporto idrico ha determinato valori più elevati dell'umidità del seme e degli acidi grassi liberi dell'olio. Relativamente agli altri parametri, ovvero il profilo degli acidi grassi e gli indici spettrofotometrici dell'olio non sono stati influenzati dai fattori colturali esaminati.

Parole chiave: Mandorlo, Acidi grassi, Indici spettrofotometrici dell'olio.

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Abbreviations. 16:0, palmitic acid; 16:1, palmitoleic acid (double bond position not determined); 18:0, stearic acid; 18:1, oleic acid; 18:2, linoleic acid; 18:3, linolenic acid.

INTRODUCTION

Several investigations concerning almond fruit growth have been published (3) (1) (8) (15). Attention has been given to chemical changes in the oil during kernel development (6) (4) (11) (12) (18). Fewer reports appear in the literature, however, regarding the influence of cultural practices, such as irrigation or rootstock, on the growth of the almond fruit. The morphological and chemical changes in different parts of the fruit during the entire growing period, as affected by irrigation, has been reported recently (13). The present work extends this study to examine some chemical changes in developing kernels, in relation to water supply and to the rootstock. Only their effect on the kernel mainly relating to chemical analyses of ripe almonds has been made available (14) (16).

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MATERIALS AND METHODS

The research was carried out on Texas variety in an experimental almond grove near Sassari. During 1988, 9 samplings were made from fruit set to crop maturity, each consisting of at least 50 fruits per plant. The experimental design consisted of 12 almond trees (6 grafted onto bitter almond and 6 onto peach), arranged in six random plots of 2 trees per plot, three irrigated and three not. Water was supplied through a key clip drip system delivering a total of 7 m^3 per tree from June to September. The analyses included moisture and oil content of the kernels, determined according to Edwards (1974). On oil extracted by Folch's reagent, free fatty acid, UV spectrophotometric indices, and relative percentages of fatty acids were determined as previously described (17).

RESULTS

The kernel moisture remained fairly constant until 9-10 weeks after fruit set (WAFS), then decreased rapidly up to 21-22 WAFS. Further on, this reduction was less pronounced (fig. 1). Higher kernel moisture was found in irrigated trees and on bitter almond grafted ones (table 1).

The rate of accumulation of total lipids in developing kernels (on a dry matter basis), from fruit set to harvesting time, may be conveniently divided into three stages, as previously reported (8) (11) (12). During the first stage (cell multiplication period), ranging from fruit set to 9-10 WAFS, a very slow accumulation of lipids was observed

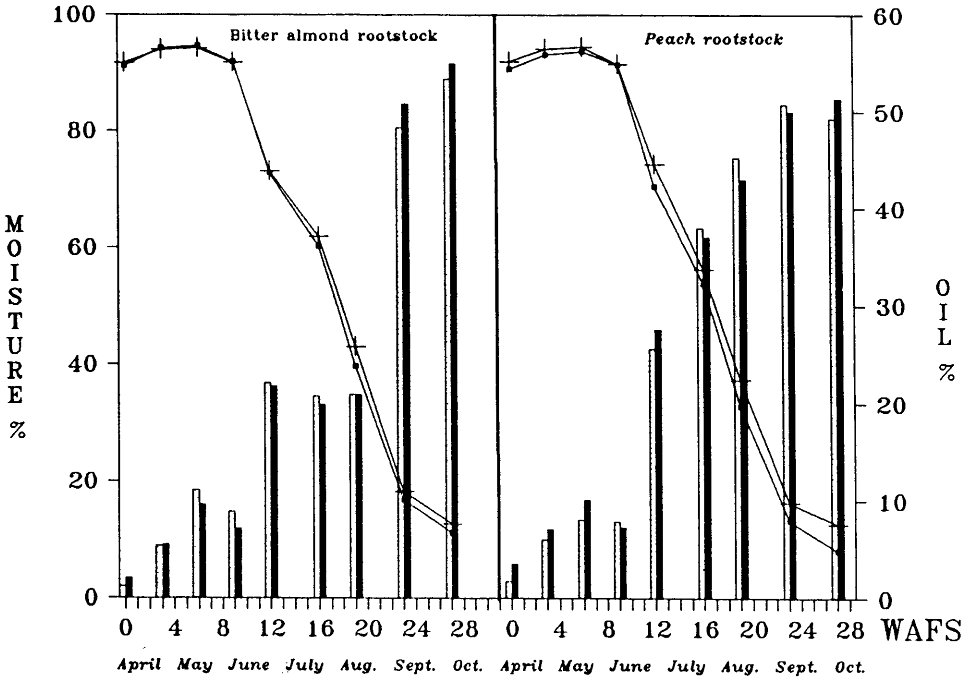

Fig. 1 - Moisture (lines) and oil content (histograms) in developing almond kernels from non-irrigated (∘, Π) and irrigated (+, ■) plots.

(fig. 1). Most of the oil was accumulated during the second stage, 2 weeks before harvesting time. During the third stage, ending at harvesting time, generally only a minor amount of lipids accumulated. The peach rootstock gave significant higher mean values in oil content during development (table 1). The higher mean value reflects an earlier oil accumulation with this rootstock (AxC interaction is significant in tab. 1). At maturity, however, differences in oil content were slight (fig. 1). The influence of irrigation was not significant.

The free fatty acid concentrations in the almond oil decreased rapidly as ripening advanced, reaching relatively low values at harvesting time (fig. 2). Higher free fatty acid levels were detected in irrigated trees grafted onto bitter almond.

Concerning the spectrophotometric indices of the oil (table 1), a rapid decrease during maturation was observed, in accordance with Galoppini and Lotti (1962). The low values recorded confirmed that conjugated polyunsaturated fatty acids are practically absent in almond oil. Neither water supply nor rootstock proved to have any influence on these parameters. The fatty acid composition changed drastically during the development of the kernel. During the first phase of lipid accumulation, high levels of saturated and essential fatty acids (linoleic and linolenic fatty acids)

Tab. 1 - Influence of rootstocks, water supply and of the sampling data (weeks after fruit set, WAFS) on the compositional changes in developing almond kernels of "Texas" variety.

Source of variations	Moisture (% f.w.)	Oil (% d.w.)	Fatty acids (relative % by wt)						Spectrophotometric indices		
			16:0	16:1	18:0	18:1	18:2	18:3	K232	K268	ΔK
Rootstocks (A)											
Bitter almond	64.37a	21.37b	12.52	0.47a	2.43b	42.56	32.84	8.41	9.03	2.88	0.041
Peach	62.27b	26.08a	12.71	0.35b	2.59a	41.82	33.09	8.84	8.64	2.71	0.038
Significance	***	*	N.S.	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Water supply (B)											
non irrigated	62.47b	23.58	12.61	0.39b	2.44b	42.22	32.05	8.74	8.83	2.79	0.041
Irrigated	64.17a	23.87	12.62	0.43a	2.58a	42.16	33.08	8.51	8.84	2.79	0.038
Significance	*	N.S.	N.S.	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Sampling data (C)											
0 wafs	91.39a	2.11g	22.15a	0.16c	3.13b	14.35d	36.42c	22.34a	24.70a	8.82a	0.074b
3 wafs	93.34a	6.00f	20.96b	0.43b	3.21b	14.02d	38.26.bc	22.04a	19.60b	6.34b	0.070c
6 wafs	94.31a	9.68e	20.05c	0.34bc	3.77a	14.12d	38.85b	21.80a	15.74c	4.76c	0.079a
9 wafs	91.68.a	7.78ef	18.68d	0.90a	2.25c	15.18d	50.28a	11.10b	11.56d	3.64d	0.065c
12 wafs	72.70b	24.27d	8.18e	0.35bc	1.43e	49.90c	39.13b	0.35c	7.65e	2.61e	0.074b
16 wafs	51.00c	28.94c	6.63f	0.36bc	1.88d	61.53d	29.46d	0.00c	4.45f	2.61e	0.030d
20 wafs	38.25d	32.51b	5.76g	0.37bc	2.19c	70.29a	21.28e	0.00c	2.21g	0.39f	0.008e
24 wafs	16.14e	49.99a	5.50g	0.39bc	2.49c	69.28a	21.60e	0.00c	1.39h	0.14fg	0.002f
28 wafs	13.46f	52.24a	5.67g	0.39bc	2.24c	70.10a	21.41e	0.00c	1.32h	0.05g	0.001g
Significance	**	**	*	**	**	**	**	**	**	**	**
Interactions											
A B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
A C	*	***	***	***	N.S.	***	**	**	***	***	***
B C	N.S.	N.S.	**	N.S.	***	***	*	N.S.	N.S.	N.S.	N.S.
A B C	N.S.	N.S.	N.S.	N.S.	***	**	**	***	N.S.	N.S.	N.S.

Carbon number: number of double bond. Means within a colunn of each section followed by a common letter are not significantly different at the 5% level by Duncan's Multiple range test.
N.S., *, **, *** = non significant or significant at the 5%, 1‰, or 1% respectively.

were observed (table 1). During the second phase, linolenic acid decreased rapidly and then disappeared; oleic acid remained relatively constant during the first 12 weeks, but eventually showed a considerable increase from ca. 20% to 70%. In the final phase, slight changes in oleic and linoleic fatty acid were recorded. Minor fatty acids (lauric, myristic, palmitoleic, hexadecadienoic and arachic) were also detected in very low concentrations from fruit set to full maturity (data not shown).

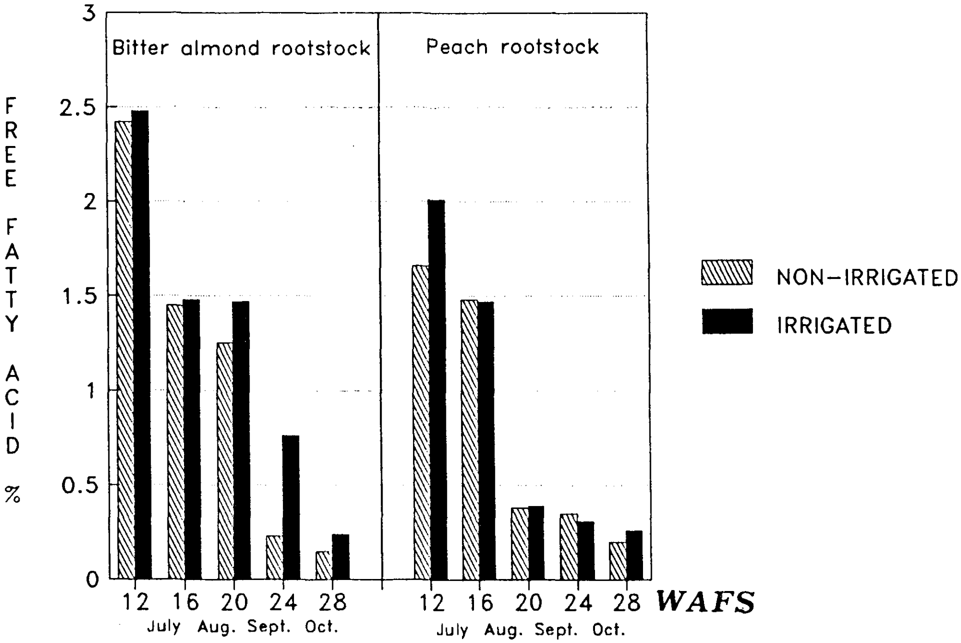

Fig. 2 - Evolution of free fatty acid in almond oil.

As regards the influence of the cultural practices tested on fatty acid composition, statistical analysis showed significant differences in palmitoleic and stearic acids in relation to rootstock and irrigation (table 1). Nevertheless, these differences were so small that there were considered to be negligible.
The main correlations found between the fatty acids in the oil of developing almond kernels are shown in table 2. Palmitic acid was inversely correlated with oleic acid and directly with linoleic and linolenic acid; stearic acid was directly correlated with linolenic acid; linoleic acid was inversely correlated with linoleic and linolenic acids.

DISCUSSION AND CONCLUSIONS.

Kernel moisture as well as the free fatty acids in the oil were higher in samples from irrigated trees. These results have considerable practical significance, since quality and stability of the almonds under warehouse conditions greatly depends upon the moisture content at harvesting time (9) (10) (17). The rate of accumulation of total lipids during the period from July to September differed in relation to the rootstock. These differences tended to disappear as ripening advanced. On the other hand, other researchers have found that factors such as variety and climate affected the pattern of changes in lipid accumulation during the development of these fruits (4)

Tab. 2 - Simple correlation between fatty acids of almond oil.

FATTY ACID (2) X	Y	LINEAR REGRESSION EQUATION	CORRELATION COEFFICENT	SIGNIFICANT LEVEL
16:0	18:1	y = 86.53 − 3.52 x	-0.981	< 0.001
16:0	18:2	y = 20.26 + 1.01 x	0.732	< 0.001
16:0	18:3	y = - 8.67 + 1.37 x	0.957	< 0.001
18:0	18:3	y = -17.62 + 10.46 x	0.789	< 0.001
18:1	18:2	y = 46.49 − 0.32 x	-0.835	< 0.001
18:1	18:3	y = 24.15 − 0.37 x	-0.920	< 0.001

(2) Carbon number of double bond.

(18). During the period of maximum accumulation of oil a decrease in starch and total soluble sugars and a gradual increase in protein content (13) (15) as well as rapid changes in the morphological, anatomical and physiological characteristics has been observed (7).

Regarding fatty acid composition, the high concentrations of palmitic, linoleic and linolenic acids during the first phase would be correlative with their incorporation into polar lipids (the preponderant lipid component in this phase) and with the formation of cell walls (18). The subsequent decrease in palmitic and linolenic acids corresponds to the decrease in phospholipids and glycolipids and to the increase in acylglycerides; the linoleic acid variation differs, since it is also a component of the triglycerides (11) (12). The high probability levels and correlation coefficients found in this work between the fatty acids would suggest that these gross changes could be interpreted in terms of metabolic interconversions. However, as the data are expressed as the relative percentage distribution of the fatty acids (and not in absolute terms per kernel), it can be shown (2) that no loss of fatty acid may occur, but simply a difference in the rate of accumulation according to the stage of development.

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