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Fruit Development Effect on Fatty Acid Composition of *Persea americana* Fruit Mesocarp

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Various samples of lipids of avocado (*Persea americana*) mesocarp belonging to four varieties (Lula, Bacon, Fuerte, Zutano) and taken at various stages of fruit development were analyzed for fatty acids by gas chromatography (GC). These cultivars were grown under the same agroclimatic Mediterranean-like conditions and during the same growing season. Evolution of fatty acids seemed to be similar among the avocado varieties studied. Intercorrelation among fatty acids and their relation to variety and fruit development were investigated by analyzing the data (154 samples) with pattern recognition techniques such as principal component analysis (PCA) and factorial discriminant analysis (FDA). These statistical techniques showed a good partition of samples among the different cultivars studied, and the first axis determined the maturity index during fruit development for all cultivars studied. By FDA, supplementary data (32), representing new avocado samples of these cultivars, were successfully classified among the cultivar groups and/or among the different stages of fruit development.

The avocado (*Persea americana* Mill., family Lauraceae) is an oleaginous fruit (Mazliak, 1970). The terminology of maturity and fruit quality is generally associated with the oil content in mesocarp (Lewis, 1978). The oil level in avocado mesocarp constitutes the basis of maturity regulations for marketed avocados, and therefore, considerable interest in determination of avocado oil content has appeared (Lewis et al., 1978; Lozano et al., 1982). Among the various horticultural varieties, four of them are now available in Corsica Island (France): Zutano variety, a Mexican race originating from the cool subtropical highland of Mexico area; Bacon and Fuerte varieties, hybrids between the Mexican and the Guatemalan races; Lula variety, hybrid between the West Indian and Guatemalan races. In the case of avocado fruit, unlike some other fruits, maturation is not associated with external changes in color. On the other hand, consumer and physiological maturity do not coincide, and therefore, consumering maturity is particularly difficult to determine. Since only sensory evaluation could determine consumering maturity, a chemical and/or a physical index of fruit development (Lozano et al., 1987), related to the results of sensory evaluation, is needed. Recently, the change in the class of lipids associated with the development of avocado fruit has been reported in a recent synthesis of research works done on this theme (Ahmed and Barmore, 1980).

In this study, we present the results obtained upon the changes in fatty acid composition during fruit development of the lipids contained in the mesocarp of the four varieties described above. Since the chemical composition is dependent on many factors such as geographic and climatic conditions, comparative results have been obtained from the same area (Mediterranean climate) and the same growing season. The 154 samples investigated in this study have been obtained from randomized selected fruits and multivariate statistical analyses, which have been successfully applied in lipids research (Gaydou et al., 1984, 1985), and have been used to distinguish among the different varieties and stages of fruit development. Supple-

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mentary samples (32), grown under similar Mediterranean climate, were also checked using factorial discriminant analysis.

EXPERIMENTAL SECTION

Fruit Samples. Four varieties of avocado trees (*P. americana* Mill.) (Lula, Bacon, Fuerte, Zutano) have been grown in the station de Recherches Agronomiques (CIRAD-INRA) of Corsica Island (France). Samples investigated (154) have been each composed by randomly selected lots of 10–12 fruits. Four stages of fruit development have been constituted: stage I, 20 weeks after flowering (WAF); stage II 25 WAF; stage III, 31 WAF; stage IV, 36 WAF. These avocados were harvested during the agronomic season of 1983, and analyses were done about 48 h after harvesting lots of fruits at each stage of development chosen.

Sample Preparation. Exposure of lipids to oxygen has been minimized by the use of a nitrogen atmosphere during extraction and derivatization. The fresh avocado fruit has been peeled and the seed removed. The freshly separated mesocarp was lyophilized for moisture determination. Lipids have been extracted from powdered mesocarp (10 g) with hexane in a 250-mL Soxhlet apparatus for 8 h. For quantification on a mass basis, an appropriated amount of internal standard, heptadecanoic methyl ester (Fluka, Buchs, Switzerland), has been added to the extracted total lipids. Fatty acid methyl esters have been then prepared by using sodium methylate in anhydrous methanol already used elsewhere (Gaydou et al., 1983; Lozano et al., 1985). This method gives consistent results with those obtained by using tetramethylammonium hydroxide reagent (Metcalfe and Wang, 1981). No significant variation was observed in the values obtained by the two methods. For the identification of fatty acid methyl esters, commercial saturated even-numbered methyl esters (Fluka) and unsaturated and polyunsaturated methyl esters (Sigma, St. Louis, MO) have been used as standards.

Gas Chromatography. A Girdel Model 3000 gas chromatograph (GC, Delsi, France), equipped with a flame ionization detector (FID) and a glass injector, has been used for the analyses. The column employed was a 25-m-long (0.32-mm-i.d.) glass capillary column coated with Carbowax 20M (film thickness 0.15 μm). Temperatures used were 190 °C for column and 250 °C for inlet and detector ovens. The inlet pressure of hydrogen used as carrier gas was 0.8 bar (split 50 mL·min^{-1}). Peak areas have been integrated by a Spectra Physics 4100 integrator. All our results were expressed as uncorrected peak area values. The amounts of fatty acids, the concentrations of which were lower than 0.1%, have been called traces.

Statistical Analysis. To evaluate the repeatability of the total fatty acid (TFA) determinations, coefficients of variation (CV) have been calculated through eight complete analyses (ca. variation within TFA data obtained from the same lyophilized mesocarp as starting material to GC analysis). Principal component analysis (PCA) has been performed by using a data set transformed into centered and reduced variables (standardized PCA). The data set was composed of the values taken by nine variables: palmitic, palmitoleic, stearic, oleic + *cis*-vaccenic, linoleic, and linolenic acids; unknown component; total fatty acid content in the extracted lipids; and the ratio of the sum of the unsaturated fatty acids to the sum of saturated fatty acids (U/S) for the 154 samples prepared as indicated above. Factor discriminant analysis (FDA) has been performed to classify into four categories the lipid samples, either for a known stage of fruit development within varieties or for a known variety within the four stages (four varieties, four stages). Thirty-two samples used as supplementary data (two samples of each variety and for each stage) were checked for classification either according to variety differentiation or according to stages of fruit development. Further descriptions of PCA and FDA are provided by Romeder (1973), Lebart et al. (1982), and Foucart (1982). The whole processing has been done on the computer (Hewlett-Packard HP 1000) of the Ecole Supérieure de Chimie of Marseilles (France).

RESULTS AND DISCUSSION

Fatty Acid Composition. Accumulation of lipids and changes in fatty acid composition of the different varieties of avocados grown during the same season in Corsica Island have been followed from the 20th week after flowering (20 WAF, stage I) to 36 WAF (stage IV). The lipids of avocado mesocarp samples have been submitted to capillary GC for fatty acid determinations. Repeatability of these determinations has been checked for the most important fatty acids. Small coefficients of variation (CV) have been obtained for oleic + *cis*-vaccenic acids and were less than 1.5%, which is comparable to the level of repeatability recommended (Afnor, 1981). Identification of fatty acids has been made by comparison with chromatograms obtained by using vegetable oils and by comparison with equivalent chain lengths (ECL) of fatty acids published recently by using capillary columns with Carbowax 20M phase (Gaydou et al., 1984; Peyronnel et al., 1984). One peak with ECL = 19.08 has not been identified and will be further called in this paper "unknown substance"; its nature is under investigation. This peak has been found in each variety, but its content has decreased during fruit development. The mean (percent by weight) and CV for the fatty acids within the Fuerte, Lula, Bacon, and Zutano varieties during the four stages of fruit development are shown in Table I. Since the *cis*-vaccenic acid peak (1–2% of the TFA content) was partially overlapped by the oleic acid peak in some chromatograms, we have used in this study the sum of these two acids for comparative interpretation. The sum of these two acids representing 57–70% in the first stage of development rises to 75–80% in stage IV. Every other fatty acid decreased gradually during fruit development. The linoleic acid content decreased from 11–14% in stage I to 8–10% in stage IV. The same evolution is observed for palmitic acid: the 11–17% in the earlier stage falls to 7–11% in the later one. For minor fatty acids as palmitoleic, stearic, and linolenic, their amount decreased or remained in the same order of scale. As for the unknown substance, the content of which is higher at all stages in the Fuerte variety (8.8% in stage I, 2.4% in stage IV), a similar reduction was observed among the other varieties of avocados. Quantitative determination of the total fatty acids (TFA) contained into the extracted lipids is achieved by the use of an internal standard. Corresponding results are given for the Zutano variety in Table I. A greater increase in TFA occurred as fruit advanced in maturity in stage I and stage II but a lesser increase occurred at more advanced maturity to stage IV, with the exception of the Fuerte variety where the rate of increase remained almost constant as maturity advanced from stage I to stage IV. The large range of variation in the main fatty acids shows that it is difficult to perform some classification among the four avocado varieties during fruit development.

As fatty acid patterns of avocado mesocarp lipids reported by several authors (Ahmed and Barmore, 1980) varied with the nature of cultivars, the stage of development of fruits, etc., it is difficult to contrast our results with theirs. Nevertheless, as the major fatty acid was always

Table I. Fatty Acid Composition (Percent by Weight) of Avocado Mesocarp during Fruit Development (Cultivars Grown under Mediterranean Climate)

	stage I (20 WAF)[a]								stage II (25 WAF)							
	Lula		Bacon		Fuerte		Zutano		Lula		Bacon		Fuerte		Zutano	
fatty acid	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV
16:0	16.80	1.07	11.50	0.40	12.80	1.06	10.80	0.80	14.20	0.67	10.70	1.48	10.20	0.67	9.60	0.65
16:1 (n - 7)	1.80	1.36	3.40	0.14	2.60	0.19	2.10	0.40	3.20	0.53	3.70	0.93	1.90	0.21	2.50	0.44
18:0	0.70	0.02	0.50	0.04	0.90	0.28	0.60	0.05	0.60	0.05	0.40	0.03	0.60	0.22	0.50	0.04
18:1 (n - 9) + 18:1 (n - 7)	62.30	2.49	64.90	2.57	60.80	2.72	70.20	3.02	67.70	1.80	73.00	2.30	68.40	3.37	76.10	1.62
18:2 (n - 6)	14.00	1.77	12.30	1.28	12.30	0.61	10.50	0.99	11.50	0.77	9.50	0.56	10.20	0.47	8.70	0.93
unknown[b]	1.80	0.89	4.70	1.31	8.80	3.83	2.50	2.60	0.90	0.35	1.10	0.51	7.10	3.93	0.60	0.53
18:3 (n - 3)	2.20	0.52	1.80	0.42	1.10	0.11	2.60	0.54	1.50	0.42	1.10	0.19	1.10	0.20	1.70	0.30
TFA[c]	70.50	6.95	67.30	5.21	68.50	6.68	45.90	8.48	89.30	4.99	83.20	5.94	71.60	6.28	71.80	11.70
U/S[d]	4.60	0.32	6.80	0.22	5.60	0.27	7.50	0.49	5.70	0.31	7.90	0.92	7.50	0.31	8.90	0.71
	stage III (31 WAF)								stage IV (36 WAF)							
	Lula		Bacon		Fuerte		Zutano		Lula		Bacon		Fuerte		Zutano	
fatty acid	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV
16:0	12.70	1.11	11.00	0.83	10.90	0.85	10.00	1.00	11.10	0.49	7.10	0.50	9.30	1.17	8.60	0.55
16:1 (n - 7)	1.80	0.30	4.00	0.52	2.20	0.49	2.00	0.39	1.40	0.57	2.40	0.38	1.50	0.09	2.20	0.35
18:0	0.60	0.07	0.40	0.04	0.50	0.08	0.50	0.05	0.60	0.19	0.40	0.02	0.60	0.05	0.50	0.04
18:1 (n - 9) + 18:1 (n - 7)	73.10	2.07	73.80	1.72	68.60	2.82	76.20	1.45	75.10	1.94	80.20	0.53	76.80	1.86	78.90	0.78
18:2 (n - 6)	9.90	1.06	8.40	0.59	10.80	1.08	8.00	0.84	9.90	0.81	8.10	0.34	8.30	0.35	7.70	0.37
unknown[b]	0.40	0.33	1.40	0.36	5.40	2.95	1.80	0.65	0.30	0.40	0.60	0.31	2.40	1.32	0.90	0.22
18:3 (n - 3)	1.20	0.15	0.70	0.04	0.90	0.15	1.10	1.18	1.20	0.22	0.80	0.07	0.60	0.04	0.80	0.10
TFA[c]	84.70	9.13	89.30	6.74	78.60	8.29	78.00	7.48	85.80	9.56	87.90	4.85	77.40	4.32	78.60	6.10
U/S[d]	6.50	0.80	7.60	0.60	7.20	0.44	8.40	0.94	7.50	0.41	11.80	1.07	8.90	1.24	9.90	0.62

[a] Weeks after flowering. [b] Unknown substance having an ECL = 19.08 on a glass capillary column coated with Carbowax 20M at 190 °C. [c] Sum of fatty acids in lipid mesocarps extracted with hexane, determined by using heptadecanoic methyl ester as an internal standard. [d] Ratio of the sum of unsaturated fatty acids [16:1 (n - 7); 18:1 (n - 9) + 18:1 (n - 11); 18:2 (n - 6); 18:3 (n - 3)] vs. the sum of saturated fatty acids (16:0, 18:0).

Table II. Eigenvalues and Percentages of Total Inertia of the Three First Principal Components Obtained in PCA for the Nine Variables Given in Table I

	Lula			Bacon			Fuerte			Zutano		
	1	2	3	1	2	3	1	2	3	1	2	3
eigenvalue	5.36	1.40	0.84	5.64	2.13	0.61	5.07	1.28	1.18	5.44	1.61	0.70
percentage	59.60	15.60	9.30	62.70	23.70	6.70	56.30	14.20	13.10	60.40	17.90	7.80
sum	59.60	75.20	84.50	62.70	86.40	93.10	56.30	70.50	83.60	60.40	78.30	86.10

oleic acid followed by palmitic and linoleic acids in the work reported therein; our results revealed more oleic content and less palmitic and palmotoleic acids. The evolution of these two last FA was in contrast, decreasing with stages of development as indicated in our results.

The use of multivariate statistical analyses is needed to try some differentiation between the varieties among the four stages of fruit development investigated.

Multivariate Statistical Analysis for Each Variety during Fruit Development. In standardized principal component analysis (PCA), the numerical values of the nine variables reported in Table I are used to classify the four varieties: Lula (38 samples), Bacon (39 samples), Fuerte (40 samples), Zutano (37 samples). The correlation matrix of the Lula variety shows a highly negative correlation coefficient between palmitic acid and the U/S ratio (r = –0.98), between oleic and linoleic acids (r = –0.92), and between palmitic and oleic acids (r = –0.91). On the other hand, positive correlation coefficients between unsaturated and saturated acids (r = 0.92) and between linoleic and linolenic acids (r = 0.92) are also observed. For the other three avocado varieties, we have also noted similar correlations.

Percentages of total inertia for each variety are given in Table II. It can be observed that the three first principal components represent 84–93% of the total variance, i.e. the total information given by the data set. Results obtained for the four studied avocado varieties are quite similar, and therefore only one graphical representation of variables and samples relative to the Bacon variety is given in Figure 1. The first principal component gives separation of stages I and IV. Stage I is characterized by a high content of palmitic and linoleic acids and stage IV by a high content of oleic acid and a higher U/S ratio. The differentiation between stages II and III is less evident, even when using axes 2 and 3 of the PCA graphical representation. Representative points of samples corresponding to stages II and III show some overlapping.

A classification according to the four stages was obtained by using factorial discriminant analysis (FDA) for each variety and gives a 100% correct attribution for Bacon, Fuerte, and Lula. For Zutano, one misclassification was observed and a sample from stage III was classified into stage IV. The factor loadings between initial variables and discriminant functions for the three FDA axis are given in Table III. The graphical representations of samples on axes 1 and 2 are given in Figure 2.

The discriminant power of axis 1 ranges from 0.88 in the case of the Zutano variety to 0.97 in the case of the Fuerte variety (Table III). Three fatty acids (palmitic, linoleic, linolenic) are highly positively loaded upon this axis 1 (r > 0.8). The sum of oleic + *cis*-vaccenic acids and the U/S ratio are negatively loaded on this axis (r < –0.8). One can notice that palmitoleic acid has a high factor loading with axis 1 in the case of Fuerte (0.98) and with axis 3 in the case of Zutano (0.94) but has a high negative factor loading along axis 2 with Lula and Bacon varieties (–0.90 and –0.91, respectively). Stearic acid has a high factor loading with axis 1 in the case of Bacon (0.99), Fuerte (0.72), and Zutano (0.91) varieties and with axis 2 in the case of Lula (0.88). The unknown substance is strongly positively loaded on axis 1 in the cases of Lula, Bacon, and Fuerte and nega-

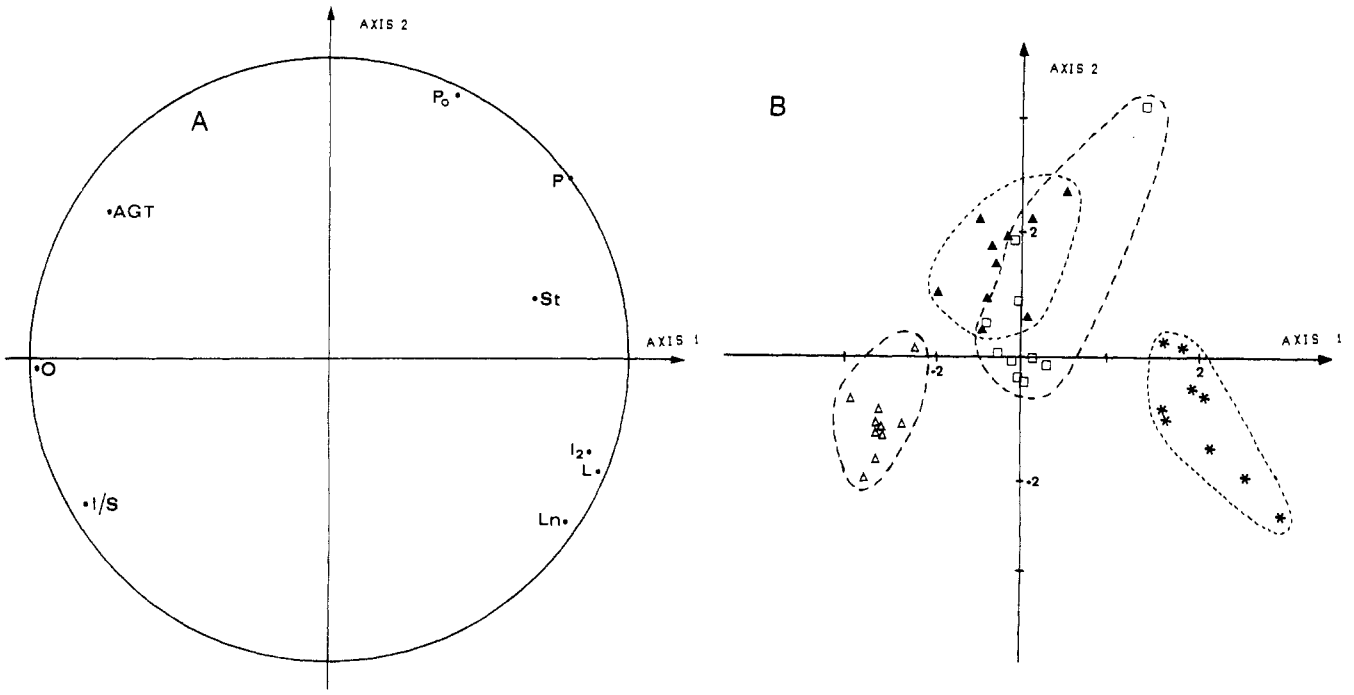

Figure 1. Graphic representation of variables (A) and samples (B) of Bacon variety onto eigenvectors 1 and 2 used in PCA for the four stages of fruit development investigated: stage I (*), stage II (□), stage III (▲), stage IV (△).

Table III. Factor Loadings between Variables and Discriminant Axes by Using FDA of Samples Related to Each Stage of Fruit Development, According to the Four Avocado Varieties

	Lula			Bacon			Fuerte			Zutano		
fatty acid	1	2	3	1	2	3	1	2	3	1	2	3
16:0	0.99	−0.10	0.12	0.81	−0.58	0.01	0.99	−0.12	0.06	0.79	−0.51	−0.35
16:1 (n − 7)	0.34	−0.90	−0.27	0.42	−0.91	0.01	0.98	−0.04	0.19	0.17	0.28	0.94
18:0	0.31	0.88	0.36	0.99	0.15	−0.06	0.72	−0.53	−0.44	0.91	0	−0.42
18:1 (n − 9) + 18:1 (n − 7)	−0.99	0.19	0.03	−0.99	0.09	0.02	−0.99	−0.16	0.05	−0.93	0.14	0.33
18:2 (n − 6)	0.99	0.11	−0.10	0.95	0.28	0.10	0.98	0.15	0.12	0.98	0.02	−0.19
unknown[a]	0.99	0.11	−0.02	0.94	0.25	−0.21	0.91	0.34	−0.22	0.54	−0.22	−0.81
18:3 (n − 3)	0.98	0.17	−0.09	0.90	0.39	0.17	0.83	0.52	−0.19	0.98	−0.02	−0.07
TFA[b]	−0.73	−0.62	−0.28	−0.91	−0.40	−0.08	−0.73	−0.06	0.68	−0.91	−0.25	0.32
U/S[c]	−0.97	0.19	−0.14	−0.83	0.55	0	−0.99	−0.05	−0.02	−0.80	0.48	0.36
discriminant power	0.92	0.69	0.34	0.94	0.87	0.39	0.97	0.64	0.58	0.88	0.70	0.49

[a-c] See footnotes in Table I.

tively loaded with axis 3 in the case of Zutano.

For each variety, axis 1 may be considered as a maturation axis.

This axis 1 differentiates the first stage of fruit development (20 WAF) in its positive part (Figure 2). The variables doing this separation are palmitic, linoleic, and linolenic acids. The last stage of fruit development (36 WAF) is also well differentiated by axis 2 in its negative part because of the sum of oleic + *cis*-vaccenic acids, the TFA, and the ratio U/S. Stage II is differentiated in the case of Lula variety by axis 2 (Figure 2C). Stages III and IV are differentiated by this axis in the case of Zutano (Figure 2D).

Thirty-two samples were used as supplementary samples to check this classification. Correct classification was observed for Bacon, Fuerte, and Lula samples. In the case of Zutano, one sample of the stage IV was classed within the stage III category.

Differentiation of Varieties during Fruit Development. Standardized PCA and FDA were used in order to differentiate each avocado variety among the four stages of fruit development investigated in this study. With PCA, varieties are generally well differentiated by the three first components for stages I, II, and IV. Some overlapping of groups is nevertheless observed for stage III. Using FDA, classification for stages I, II, and IV is 100% correct for each variety observed. Only one misclassification is noted for stage III. The factor loadings between variables and discriminant functions are given in Table IV. The graphical representation of samples on axes 1 and 2 are given in Figure 3.

For stage I of fruit development (Figure 3A), axis 1 differentiates Zutano samples from the others and its discriminant power is about 0.97 (Table IV). The variables highly correlated with this axis are oleic + *cis*-vaccenic (0.99), linoleic (−0.81), and linolenic (0.80) acids, TFA (0.93), and the ratio U/S (0.87). The distinction between Lula and Fuerte varieties has occurred upon axis 2 (discriminant power 0.88). This axis is negatively loaded with palmitoleic acid (−0.79) and the unknown substance (−0.78) and positively loaded with palmitic acid (0.75).

For stage II (Figure 3B), Lula variety is differentiated from the other ones on axis 1 (discriminant power 0.90). Palmitic (0.89) and linoleic (0.75) acids are strongly positively loaded on this axis. Axis 2 (discriminant power 0.88) separates Zutano from Bacon and Fuerte varieties. It can be noted that oleic + *cis*-vaccenic acids and linolenic acid have high factor loadings on axis 2 (0.81 and 0.83, respectively).

On stage III (Figure 3C), axis 1 (discriminant power 0.94)

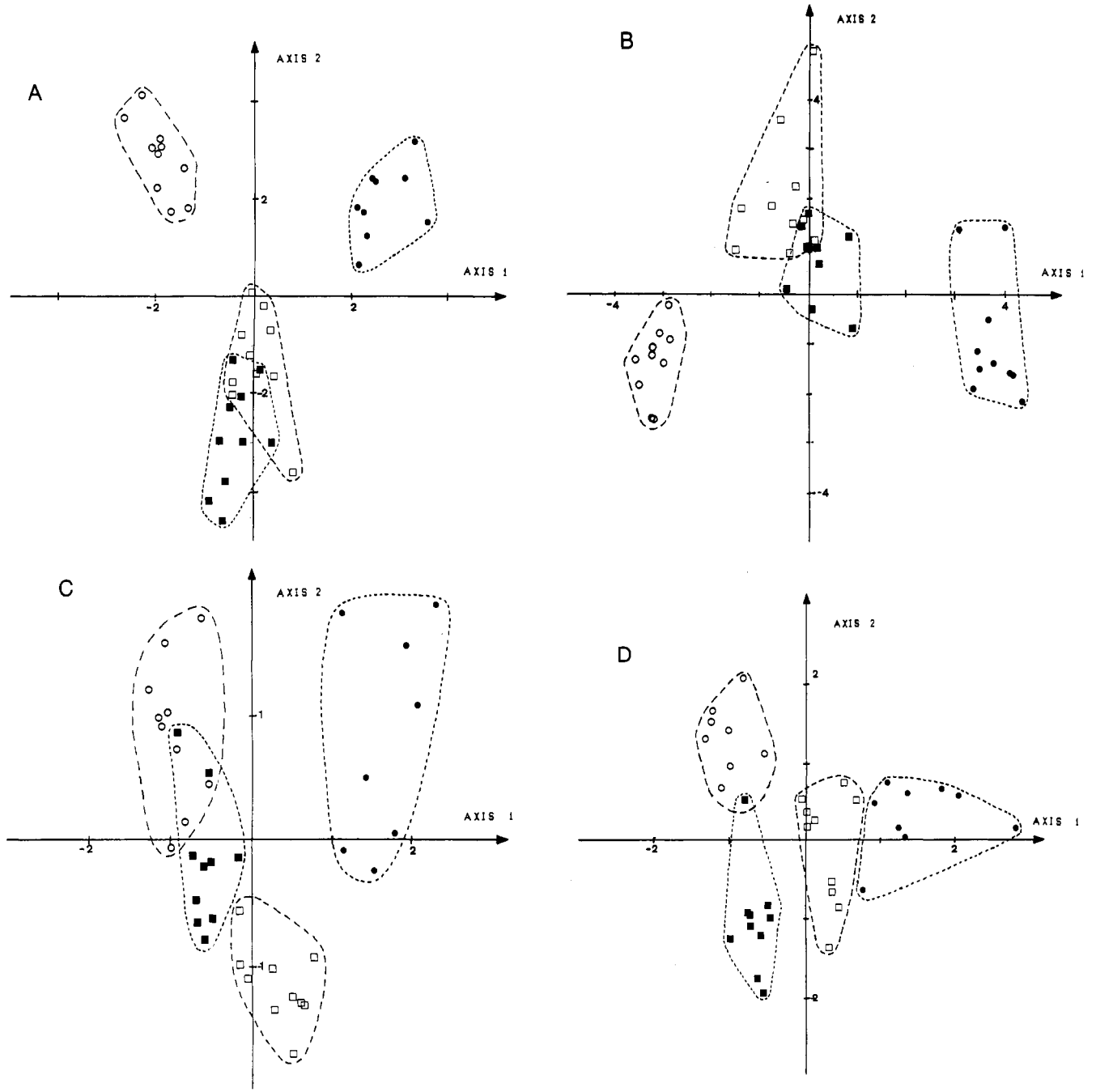

Figure 2. Graphic projection of the four stage samples of avocado fruit development onto axes 1 and 2 investigated in FDA: Bacon (A), Fuerte (B), Lula (C), Zutano (D); stage I (●), stage II (□), stage III (■), stage IV (○).

Table IV. Factor Loadings between Variables and Discriminant Axes by Using FDA for the Avocado Variety Samples According to the Four Stages of Fruit Development

	stage I[a]			stage II[b]			stage III[c]			stage IV[d]		
fatty acid	1	2	3	1	2	3	1	2	3	1	2	3
16:0	−0.65	0.75	0.03	0.89	−0.37	−0.25	−0.33	0.42	0.84	0.77	0.61	0.19
16:1 (n − 7)	−0.06	−0.79	0.60	0.13	−0.10	−0.98	0.67	−0.66	0.33	−0.55	−0.83	0.05
18:0	−0.62	−0.18	−0.76	0.25	−0.46	0.85	−0.55	0.77	0.31	0.35	0.93	−0.04
18:1 (n − 9) + 18:1 (n − 7)	0.99	0.05	0	−0.51	0.81	−0.30	−0.58	−0.80	−0.13	−0.69	−0.72	−0.07
18:2 (n − 6)	−0.81	0.47	0.35	0.75	−0.66	0.05	0.22	0.95	0.19	0.89	0.30	−0.33
unknown[a]	−0.55	−0.78	−0.28	−0.34	−0.57	0.75	0.64	0.59	−0.49	−0.64	0.75	0.12
18:3 (n − 3)	0.80	0.59	0.08	0.56	0.83	−0.03	−0.94	0.28	−0.19	0.95	0.30	0.07
TFA[f]	−0.93	0.02	0.38	0.64	−0.36	−0.67	0.20	−0.47	0.86	0.40	−0.38	−0.83
U/S[g]	0.87	−0.49	0.08	−0.81	0.58	0.05	0.11	−0.64	−0.76	−0.68	−0.69	−0.24
discriminant power	0.97	0.88	0.70	0.90	0.88	0.77	0.94	0.85	0.57	0.91	0.88	0.69

[a] 20th week after flowering (WAF). [b] 25 WAF. [c] 31 WAF. [d] 36 WAF. [e-g] See footnotes in Table I.

separates Bacon and Fuerte from the two other varieties. The fatty acids responsible for this differentiation are palmitoleic, linoleic, and the unknown substance. Fuerte is separated from the Bacon group on axis 2, which is highly correlated with oleic + *cis*-vaccenic and linoleic acids. The Zutano group is not completely separated from

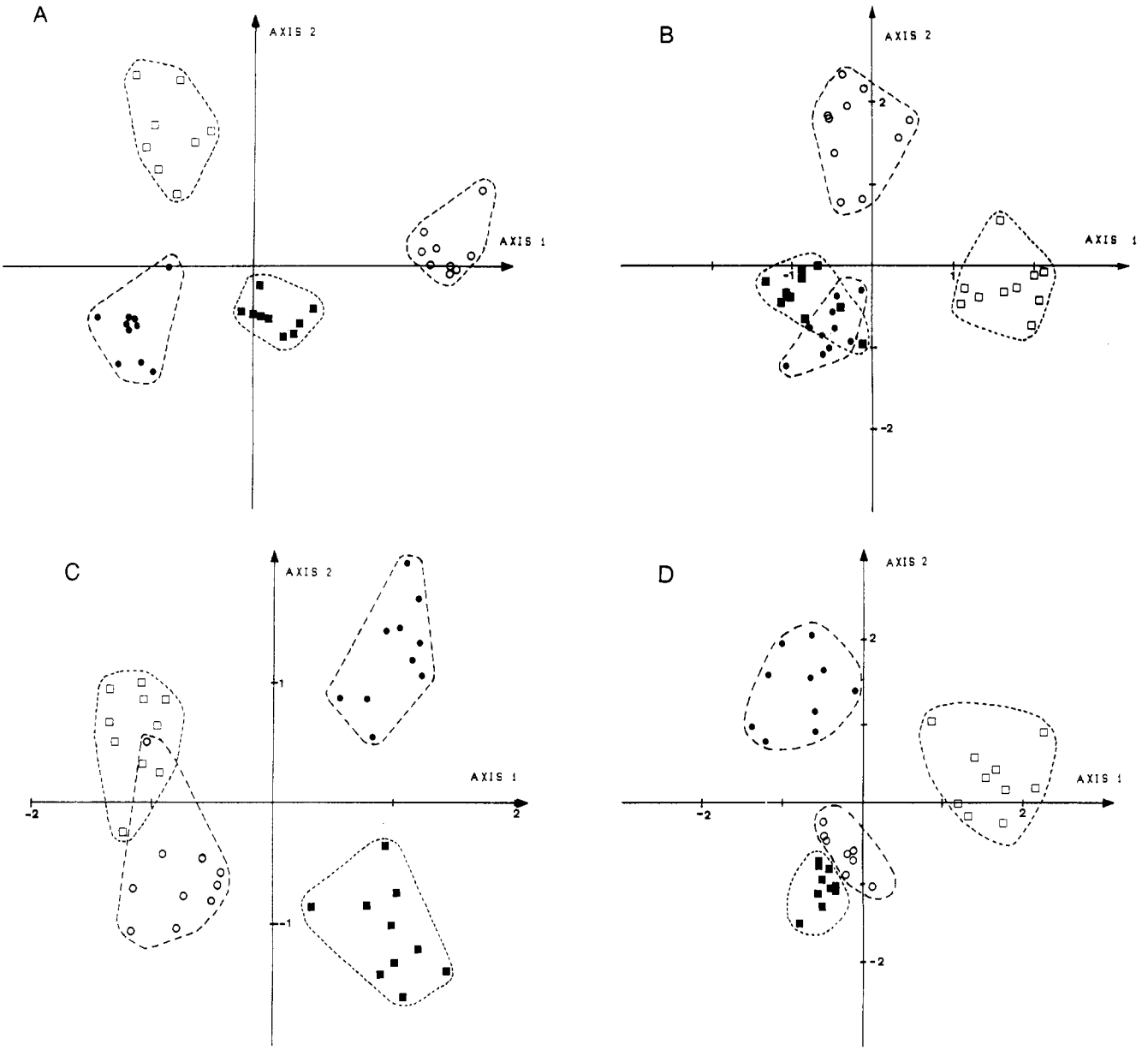

Figure 3. Graphic projection of the four variety samples of avocado fruits harvested at stage I (20 WAF, A), at stage II (25 WAF, B), at stage III (30 WAF, C), and at stage IV (36 WAF, D), onto axes 1 and 2 investigated in FDA: Bacon (■), Fuerte (●), Lula (□), Zutano (○).

the Lula group, and one misclassification is observed.

On stage IV (Figure 3D) of fruit development, complete separation of the four varieties occurs. The Lula group, which has a higher content in linolenic (1.2%), linoleic (9.9%), and palmitic (11.1%) acids, is well separated from the other groups since these acids have very high factor loadings on axis 1. Fuerte group is separated from Bacon and Zutano groups on axis 2. Indeed, the stearic acid (0.6%) and unknown substance (2.4%) contents are higher in the two varieties: Bacon and Zutano.

Supplementary data were also used to check the classification during fruit development. Among the 32 samples checked, only one, belonging to stage III was misclassified within the stage IV category.

CONCLUSION

The use of fatty acid composition in the differentiation of various stages of fruit development has been successfully checked, showing that such family compounds could be used as a chemical index of fruit development. Furthermore, the differentiation of various varieties of avocados grown in the same agroclimatic Mediterranean area has been made for fruits having the same stage of fruit development or age of maturity. Application of statistics to fatty acid analysis data obtained in this work leads to identification of some linear combination of fatty acids such as oleic, linoleic, and stearic, which are the most representative compounds of a variety or of a stage of development. The data set herein constituted should be used to identify unknown avocado variety among the four varieties grown under Mediterranean climate and, to a less extend, to be informed of the degree of maturity of a just cropped avocado sample.

We are implementing this data set with the analysis of avocado samples grown under tropical climate, the fatty acid compositions of which are fairly different for those studied.

Nevertheless, fatty acids are not the main chemical compounds present in oil. They are in fact obtained after esterification of triglycerides, which are the real chemical compounds biosynthesized in avocado oil during fruit development. One could wonder to what extent a similar

study on triglycerides could lead to more complete information and more valuable results for avocado maturity determination. Such research work is worth undertaking.

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Selenium Content of Vegetables, Fruits, and Cereals in Galicia (Northwest Spain)

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The selenium content of 60 samples of vegetable foods has been determined fluorimetrically. After wet destruction of organic matter, the complex 4,5-benzopiazselenole was formed by reaction between Se(IV) and 2,3-diaminonaphthalene and extracted with cyclohexane. The results suggest that the population of Galicia (NW Spain) consumes an average 11.20 μg of selenium/person per day in food of vegetable origin.

The nutritional value of selenium has been studied in experimental animals for ever 20 years (Schwarz and Foltz, 1957), and there has been growing interest in its role as an essential trace element for animals (NRC Agricultural Board, 1971) and for man (Levander, 1975). It has been found, for example, that selenium-supplemented diets effectively prevent the appearance of certain nutritional disorders in battery chickens and rats (Hartley, 1959).

According to Morris and Levander (1970), the selenium content of human food it is varied. Vegetables and fruit are generally poor in selenium (0.01 μg/g), though mushrooms (Pipponen, 1984), garlic (Olson and Palmer, 1984), and horseradish (Levander, 1976) can contain quite large amounts. The selenium content of plants is in any case strongly influenced by the quantity of biologically available selenium in the soil in which they grow (Kubota et al., 1967), and hence by their geographical origin. For example, Mondragon and Jaffe (1976) have found that various food products contain higher selenium levels when acquired in the marketplace in Caracas than when bought in the United States.

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With respect to their intrinsic capacity for accumulation of Se, plants may be divided in three groups (Rosenfield and Beath, 1964): group I, plants that may contain up to 10 000 μg/g; group II, plants rarely containing more than a few hundred micrograms/gram; group III, plants rarely containing more than about 30 μg/g, among them fruit and cereals.

MATERIALS AND METHODS

Apparatus. Ordinary laboratory glassware was employed. In order to eliminate fluorescence due to detergents and samples, all glassware was washed after each use with tap water, 1:1 nitric acid, and distilled water.

Fluorimetric determinations were carried out on a Farrand Model A4 fluorimeter (Farrand Optical Co. Inc.) equipped with a mercury vapor lamp and 1-cm light path cells.

Reagents. *Selenium Standard Solution.* A vial of Merck Titrisol selenium standard solution containing 1.000 ± 0.002 g of Se is made up to 1 L, with deionized distilled water. Working solutions are derived from this standard by successive dilutions with 0.1 M HCl.

2,3-Diaminonaphthalene (DAN) Solution. Solutions (0.1%, (w/v) of DAN in 0.1 M HCl are made up daily and extracted before use with 25 mL of cyclohexane/100 mL of DAN to eliminate fluorescence.

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