Effects of Talc Addition and Operating Mode on the Quality and Oxidative Stability of Virgin Olive Oils Obtained by Centrifugation

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Continuous centrifugation, a widely used procedure for extraction of virgin olive oil, involves crushing olives, mixing the olive paste, and centrifugation with or without water addition ("three phase" or "two phase" modes, respectively). Virgin olive oils were obtained following both procedures, with and without talc addition. Acidity value, peroxide index, UV absorption at 270 and 232 nm, glyceridic polar compounds, oxidized triglycerides, diglycerides, iron, copper, tocopherols, phenolic compounds, and oxidative stability were determined and the results statistically analyzed. The talc addition gave rise to a small increase in the oil stability and a slight decrease in oxidized triglyceride levels. The oils obtained by the "two phase" mode showed a greater concentration of phenolic compounds than the homologous oils obtained by the "three phase" mode. Oils processed by the "three phase" mode showed a significant correlation between their stability and their phenolic concentration.

Keywords: *Virgin olive oil; talc addition; centrifugation mode; quality; stability*

INTRODUCTION

Virgin olive oil is obtained using only physical methods involving three successive operations: the crushing of olives in a hammer crusher, mixing of the olive paste in a mixer and separation of the oil by means of presses or centrifuges. In regions of abundant olive crops, centrifugation is the most commonly used procedure since large amounts of olive fruits have to be processed in a short time. There are two centrifugation modes, "three and two phase". In the former, a significant flow of water is added before the centrifugation step, yielding separately oil, residual water, and solid waste. In the latter, little or no water is added, giving rise only to oil and a plastic paste containing the vegetable water and the solids. The "three phase" continuous centrifugation is the most widely used operating procedure to date. However, the "two phase" mode was introduced in Spain four years ago, and is now widely used because it leads to a large decrease of liquid waste, resulting in a marked reduction of environmental pollution.

During the mixing step, oil drops combine, facilitating the release of the oil during centrifugation. However, some olive varieties, such as Hojiblanca and, in general, olive fruits which are only slightly ripe, render emulsions, giving rise to the so-named "difficult paste". In this case, part of the oil is lost with the residues, lowering oil yield. In order to break the emulsion, time or temperature of mixing could be increased, but a loss of oil quality is observed. Another practice which avoids the formation of "difficult paste" consists of piling the fruits in the olive storage area for several days before milling. During this storage, breakage of the cell walls facilitates the oil release. However, this practice leads to the development of anomalous fermentations reducing the oil quality greatly.

In order to solve the problem, the addition of micronized talc (hydrated magnesium silicate of particle size lower than 40 μm) was introduced in the late 1970s. Talc is continuosly added to the olive paste at the mixer inlet in proportion of approximately 1% and is eliminated during centrifugation together with the solid residue. The improvement of the paste texture and the reduction of the emulsion volume allow the time and temperature of mixing to be decreased, while increasing the centrifugation effectiveness. Therefore, the talc addition helps to yield oil with lower water and suspended solids contents, as well as residues with lower fat content (Muñoz *et al.,* 1979; Muñoz & Alba 1980). Since the use of talc does not alter the fatty acid composition of the oil or modify its organoleptic characteristics, the quality of the oil is comparable to that of oil obtained without this additive (Alba *et al.,* 1982). In Spain, the use of talc free from asbestos and heavy metals in olive oil extraction was authorized and regulated by the Ministry of Health (Order of 13 January 1986). Nowadays, talc is added when emulsions or "difficult pastes" are formed in the mixer.

In this study, possible variations in the oil quality and oxidative stability related to the use of talc were examined. Simultaneously, the possible changes attributed to the "two phase" centrifugation mode were also investigated. In the first case, the work was done on pairs of virgin olive oil samples obtained with and without talc under the same conditions. In the second case, several olive cultivars were processed in the two centrifugation modes in the same oil mill. The oil samples were analyzed in the Instituto de la Grasa and the results statistically discussed.

EXPERIMENTAL PROCEDURES

Sample Preparation. In Table 1, the cultivar variety, origin, and ripeness of olive fruits used for sample preparation are shown. Oil samples were obtained in industrial oil mills located in the production areas of three European countries, operating in the habitual conditions, during the season 1993/ 1994 (Table 1). Pairs of samples (t and n series) were obtained in a short time, first without talc addition and afterward with talc. In the oil mill located in Seville, four olive cultivars were processed in "two and three phase" modes. Finally, two samples were obtained in Tunisia by press and centrifuge with talc addition. The olive oil samples were sent to the International Olive Oil Council (IOOC), where they were coded and

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Table 1. Description of Olive Characteristics, Oil Mills, and Oil Obtention Procedures

olive (symbol)	ripeness index	oil mill location	oils obtained with talc		oils obtained without talc	oil obtention procedure	
			sample code	% talc added	sample code	mode	water/paste[a] ratio
Hojiblanca I (H$_I$)	6.0	Cabra (Spain)	1t	1.5	1n	3ph[b]	0.23
Hojiblanca II (H$_{II}$)	6.1	Aguilar (Spain)	2t	0.5	2n	2ph[c]	0
Lechin (L)	5.7	Seville (Spain)	3t	1	3n	3ph	0.37
			4t	1	4n	2ph	0
Carolea I (C$_I$)	(d)	Lamezia Terme (Italy)	5t	3	5n	3ph	0.63
Carolea II (C$_{II}$)			6t	3	6n	3ph	0.63
Carolea III (C$_{III}$)			7t	3	7n	3ph	0.63
Arbequina (A)	3.3	Seville (Spain)	8t	1	8n	3ph	0.36
			9t	1	9n	2ph	0
Galega (G)	7	Moura (Portugal)	10t	1	10n	3ph	0.40
Cobrançosa (Co)	5	Moura (Portugal)	11t	2	11n	3ph	0.40
Picual I (P$_I$)	4.1	Seville (Spain)	12t	1	12n	3ph	0.26
			13t	1	13n	2ph	0
Picual II (P$_{II}$)	4	Moura (Portugal)	14t	2	14n	3ph	0.40
Chamlali (Ch)	(d)	Chaal (Tunisia)	15	(d)		press	0
			16	(d)		3ph	0.43

[a] Ratio between water (L/h) added in the centrifuge and olive paste (kg/h). [b] 3ph = "three phase". [c] 2ph = "two phase". [d] Unknown.

forwarded to the Instituto de la Grasa. The samples were filtered through filter paper and stored at −18 °C until analysis.

Analytical Methods. Determination of acidity value, peroxide index, UV light absorption (K232 and K270), and fatty acid composition were carried out following the analytical methods described in Regulations EEC/2568/91 and EEC/1429/92 of the European Union Commission.

Acidity value, given in % of oleic acid, was determined by titration of a solution of oil in ethanol−ether 1:1 with ethanolic potash.

Peroxide index, given in milliequivalents of active oxygen per kilogram of oil (mequiv/kg), was determined as follows: A mixture of oil and chloroform−acetic acid was left to react with potassium iodide solution in darkness; the free iodine was then titrated with a sodium thiosulfate solution.

K232 and K270 extinction coefficients (absorption of a 1% solution of oil in cyclohexane at 232 and 270 nm, respectively, with 1 cm of pass length) were measured on UV spectrophotometer (Hitachi U-1100).

For the determination of the fatty acid composition, the methyl esters were prepared by vigorous shaking of a solution of oil in hexane (0.2 g in 3 mL) with 0.4 mL of 2 N methanolic potash. The methyl esters were analyzed by gas chromatography on a fused silica column (60 m length × 0.25 mm i.d.) coated with SP-2380 phase (0.20 μm thickness).

Polar glyceridic compounds were isolated by fractionating the oil on a silica gel (Merck G60) column with hexane−ether 90:10 (Pérez-Camino *et al.,* 1992). Polar compounds were eluted from the column with ether, the solution was evaporated to dryness, and the residue was weighed. For the determination of oxidized triglycerides (OxTGs) and diglycerides (DGs), the residue was redissolved in tetrahydrofuran and analyzed by high performance size exclusion chromatography (Hewlett-Packard 1050) using two columns in series (Hewlett-Packard, PL-gel, particle size 5 μm, 300 mm × 7.5 mm i.d.), the first with a pore size of 500 Å and the second of 100 Å. Tetrahydrofuran was used as eluent at a constant flow of 1 mL/min. A refractive index detector (Hewlett-Packard HP-1047A) was used for detection.

Iron and copper contents were determined on an atomic absorption spectrophotometer (Perkin-Elmer 3030) equipped with a graphite furnace (HGA-400) and an automatic sample injector (AS-40). A solution of oil in methyl isobutyl ketone was prepared and directly placed on a L'Vov platform put in the pyrolized carbon tube (Martín-Polvillo *et al.,* 1994). The standard curve method was used.

Tocopherols were evaluated following the IUPAC Standard Method Num. 2432 (1992). A solution of oil in hexane was analyzed by high performance liquid chromatography (Hewlett-Packard 1050) on a silica gel column (Merck, Supersher Si60, particle size 4 μm, 250 mm × 4 mm i.d.), eluting with hexane−

2-propanol 99:1 at flow rate of 1 mL/min. A fluorescence detector (Shimadzu RF-535) with the excitation wavelength set at 290 nm and emission wavelength at 330 nm was used.

Phenolic compounds were isolated by extraction of a solution of oil in hexane with water−methanol 60:40 for three times. To a suitable aliquot of the combined extracts, Folin−Ciocalteau reagent (Merck) was added. The absorption of the solution at 725 nm was measured on a spectrophotometer (Hitachi U-1100). Results are given as mg of caffeic acid/kg of oil (Gutfinger, 1981).

For evaluating the stability, the oxidation induction time measured by the Rancimat apparatus (Metrohm CH 9100) was used. A flow of air (10 L/h) was bubbled through the oil heated at 100 °C and cold water, successively. In this process, the volatile oxidation products were stripped from the oil and dissolved in the water, increasing the water conductivity. The time taken to reach a fixed level of conductivity was measured (Gutiérrez, 1989).

Statistical Analysis. Variance analysis of the sets of results was carried out by means of the Statistica software (StatSoft Inc.) using the *t*-test for dependent samples. Differences were considered statistically significant if probability was greater than 95% (*p* level <0.05). Correlations between variables were studied by means of regression lines and coefficients of correlation (*r*), verifying the statistical significance.

RESULTS AND DISCUSSION

Virgin olive oils were obtained by centrifugation since this is the procedure in which talc addition achieves the greatest improvement of the working conditions. Fruits of different olive cultivars were processed with talc and afterward without talc; thus, talc addition was the only variation between each series of samples. Experiments on the effects of centrifugation in "three and two phase" modes were carried out in a single oil mill with three olive cultivars using the water/paste ratios shown in Table 1.

To characterize oil quality, the analytical parameters acidity value, peroxide index, K232, K270, polar glyceridic compounds, oxidized triglycerides, and diglycerides were chosen. Oxidative stability was evaluated by the Rancimat procedure since it is a fast and repetitive analytical method (Gutiérrez, 1989). Other variables, such as iron, copper, α-tocopherol, γ-tocopherol, and phenolic compounds, which are probably involved in oxidation processes, were also determined. The results of the determinations of acidity, peroxide index, and UV absorption (Table 2) indicate that the parameter

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Table 2. Hydrolytic and Oxidative Parameters Found in Olive Oils Obtained with and without Talc in "Two" and "Three Phase" Procedures

cultivar, centri-fugation mode	acidity (%) with talc	acidity (%) without talc	peroxide index (mequiv/kg) with talc	peroxide index (mequiv/kg) without talc	K270 with talc	K270 without talc	K232 with talc	K232 without talc	polar compounds (%) with talc	polar compounds (%) without talc	OxTGs (g/kg) with talc	OxTGs (g/kg) without talc	DGs (g/kg) with talc	DGs (g/kg) without talc
H_I, 3ph	0.54	0.55	10.1	11.3	0.12	0.10	1.55	1.38	2.77	2.86	5.5	5.4	14.2	16.1
H_{II}, 2ph	0.27	0.25	8.6	9.0	0.10	0.12	1.38	1.39	2.24	2.35	4.8	5.4	13.3	13.6
L, 3ph	0.20	0.19	14.0	13.2	0.10	0.12	1.82	1.92	4.28	4.32	17.1	18.4	19.3	19.7
L, 2ph	0.20	0.20	13.3	12.8	0.12	0.12	1.82	1.85	4.12	4.11	16.1	17.8	16.4	18.6
C_I, 3ph	0.42	0.38	13.5	13.5	0.11	0.13	1.96	2.05	2.61	2.90	5.9	5.1	15.5	18.4
C_{II}, 3ph	0.30	0.30	14.7	14.0	0.13	0.11	1.73	1.71	2.65	2.89	6.1	8.0	16.1	16.2
C_{III}, 3ph	0.43	0.43	15.1	14.1	0.11	0.10	1.80	1.91	3.50	3.30	8.2	8.2	20.0	18.4
A, 3ph	0.17	0.18	9.5	9.7	0.12	0.12	1.43	1.46	3.25	3.31	14.4	13.8	14.5	15.7
A, 2ph	0.27	0.28	9.8	9.7	0.12	0.11	1.70	1.59	3.18	2.94	8.1	8.8	18.6	16.9
G, 3ph	0.38	0.40	7.5	7.9	0.10	0.09	1.68	1.63	2.64	2.60	7.1	8.1	13.8	12.9
Co, 3ph	0.35	0.35	7.3	8.5	0.14	0.16	1.81	1.98	2.34	2.82	6.3	8.8	13.7	14.2
P_I, 3ph	0.26	0.23	10.9	10.2	0.15	0.15	1.69	1.68	2.94	2.73	7.9	5.8	17.4	18.0
P_I, 2ph	0.25	0.24	11.0	10.9	0.15	0.15	1.66	1.67	2.98	2.93	8.9	9.3	17.1	16.6
P_{II}, 3ph	0.18	0.19	7.3	7.4	0.16	0.16	1.66	1.67	2.41	2.74	4.1	7.3	16.8	16.2
Ch, Pr	0.32		11.9		0.13		2.00		2.79		6.0		16.2	
Ch, 3ph	0.32		11.8		0.12		1.97		2.88		7.0		15.4	

Table 3. Concentration of Some Minor Components and Stability of Olive Oils Obtained with and without Talc in "Two" and "Three Phase" Procedures

cultivar, centri-fugation mode	Fe (ppm) with talc	Fe (ppm) without talc	Cu (ppb) with talc	Cu (ppb) without talc	α-tocopherol (mg/kg) with talc	α-tocopherol (mg/kg) without talc	γ-tocopherol (mg/kg) with talc	γ-tocopherol (mg/kg) without talc	polyphenols (mg/kg) with talc	polyphenols (mg/kg) without talc	stability (hour) with talc	stability (hour) without talc
H_I, 3ph	4.54	4.04	203	243	208	230	11	15	50	46	17.0	18.5
H_{II}, 2ph	4.08	3.27	220	280	241	250	16	15	108	106	29.4	28.8
L, 3ph	4.98	4.61	65	68	138	174	10	13	160	175	24.8	26.9
L, 2ph	3.87	4.63	66	72	128	178	13	11	175	177	26.2	25.1
C_I, 3ph	0.01	0.01	68	89	106	116	4	5	144	126	31.4	29.7
C_{II}, 3ph	0.01	0.01	121	106	117	103	5	4	180	174	51.0	40.1
C_{III}, 3ph	0.01	0.01	124	112	114	124	5	4	80	82	21.1	24.2
A, 3ph	2.16	2.15	67	73	185	189	1	1	109	116	26.9	28.4
A, 2ph	1.36	2.06	75	70	205	189	2	2	119	123	40.2	37.7
G, 3ph	1.79	2.04	73	67	185	179	10	12	115	90	44.3	36.9
Co, 3ph	2.36	3.20	67	62	316	283	19	19	286	270	58.6	48.1
P_I, 3ph	2.62	3.45	69	55	222	239	22	26	165	155	78.0	77.3
P_I, 2ph	3.94	4.40	70	52	243	223	24	24	198	173	83.1	80.6
P_{II}, 3ph	1.74	2.08	55	50	199	198	20	20	382	337	122.4	112.9
Ch, Pr	0.25		146		239		4		214		26.1	
Ch, 3ph	0.27		178		240		7		175		23.5	

Table 4. Mean Values of Fatty Acid Composition (%) and Oxidative Susceptibility (OS) of the Olive Oil Samples

olive cultivar	samples	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	OS[a]
H_I	1t, 1n	7.1	0.4	4.1	78.6	6.5	0.5	422
H_{II}	2t, 2n	6.8	0.4	3.5	78.1	7.4	0.6	470
L	3t, 4t, 3n, 4n	10.3	0.7	2.0	75.2	8.5	0.7	530
C_I	5t, 5n	12.5	1.4	3.1	73.2	5.6	0.4	362
C_{II}	6t, 6n	11.9	1.4	3.1	74.4	6.3	0.5	409
C_{III}	7t, 7n	10.9	1.4	2.6	75.5	6.1	0.5	403
A	8t, 9t, 8n, 9n	11.5	1.2	1.9	75.2	7.5	0.4	456
G	10t, 10n	12.7	1.7	2.4	76.4	3.4	0.5	279
Co	11t, 11n	8.3	0.6	5.0	76.6	5.3	0.6	370
P_I	12t, 13t, 12n, 13n	9.7	0.8	3.7	79.9	2.6	0.5	250
P_{II}	14t, 14n	8.3	0.5	3.7	81.7	2.6	0.5	244
Ch	15, 16	16.7	1.9	2.9	61.3	15.0	0.5	787

[a] Oxidative susceptibility (OS) = monounsaturated + $(45 \times C18:2) + (100 \times C18:3)$.

values are within the normal ranges for high quality oils since they fulfilled the regulations of the European Union Commission (EEC/656/95 and posterior modification EEC/656/95) for extra virgin olive oils. Carolea oils (samples 5−7) show different acidity, OxTGs (Table 2), phenols, stability (Table 3), and fatty acid composition (Table 4); this indicates that the three oil samples were obtained from different olive lots, and therefore, they are coded as C_I, C_{II}, and C_{III}. In agreement with Alba *et al.* (1982), no significative differences were found in the fatty acid compositions. The great variability of palmitic, palmitoleic, oleic, and linoleic acid concentra-

tions in the oil samples (Table 4) indicates that the experiments include an extensive range of olive oils.

As far as the minor components are concerned (Table 3), the olive lot determines the range of tocopherols and copper concentrations in the oil. In the same way, the phenol and iron concentrations seem to be also related to the olive cultivar, but a greater variability of values is observed.

After comparison of the results obtained from the experiments with and without talc addition, it can be seen that differences in stability are the only ones with statistical significance (Table 5). The quality param-

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Table 5. Influence of Talc Addition on Stability and Concentration of Phenolic Compounds[a]

oil obtention procedure			rancimat stability		phenolic compounds	
talc addition	centrifugation mode	samples	difference between means (h)	statistical significance (p level)	difference between means (mg/kg)	statistical significance (p level)
yes	2 and 3 phases	1t−14t	+2.80*	0.0483*	+7.6	0.1058
no		1n−14n				
talc ≤1%	2 phases	2t, 4t, 9t, 13t	+1.68*	0.0413*	+5.2	0.4905
no		2n, 4n, 9n, 13n				
yes	3 phases	1t, 3t, 5t−8t, 10t−12t, 14t	+3.25	0.1038	+10.0	0.0990
no		1n, 3n, 5n−8n, 10n−12n, 14n				
talc ≥2%	3 phases	5t−7t, 11t, 14t	+5.90	0.1036	+16.6	0.1054
no		5n−7n, 11n, 14n				
talc ≤1.5%	3 phases	1t, 3t, 8t, 10t, 12t	+0.60	0.7511	+3.4	0.6488
no		1n, 3n, 8n, 10n, 12n				

[a] (*)Difference is statistically significant at $p < 0.05$ (confidence limit greater than 95%).

Table 6. Influence of Centrifugation Mode on the Stability and Concentration of Phenolic Compounds[a]

operating mode	samples	rancimat stability		phenolic compounds	
		difference between means (h)	statistical significance (p level)	difference between means (mg/kg)	statistical significance (p level)
3 phases	4n, 9n, 13n, 4t, 9t, 13t	−5.10	0.0711	−14.1*	0.0239*
2 phases	3n, 8n, 12n, 3t, 8t, 12t				

[a] See Table 5, footnote *a*.

eters acidity, peroxide index, UV absorption, polar compounds, and DGs are not modified by talc addition. Nevertheless, the use of talc during the "two phase" process seems to diminish the formation of OxTGs since negative differences of −0.85 and −1.36 mg/kg are found in "two phase" oils and in "three phase" oils using talc concentration greater than 2%. The statistical probability of such differences is low (*p* level 0.061 and 0.1472, respectively).

Analyzing the effect of talc on the stability in different operating modes, it can be seen (Table 5) that the differences are statistically significative in oils obtained by "two phase" mode but the significance level decreases in the oils obtained by "three phase". Talc concentrations lower than 1.5% only produce an increase of stability in "two phase" oils. Nevertheless, talc concentrations greater than 2% increase the stability but with a lower level of significance. Although the talc addition does not produce differences with statistical significance on the phenolic compounds, such increases can be observed for quantities greater than 2% in the "three phase" process.

Respective to operating modes, a decrease of phenols in the "three phases" is observed (Table 6). A decrease in stability is also seen, although with a lower level of significance. No differences are found in the remaining variables. The decrease of phenolic compounds can be explained with their water solubility; since higher water/paste ratios are used in the "three phase" centrifugation mode (Table 1), greater amounts of phenols are eliminated with water wastes in this operating mode.

The relationship between stability and concentration of phenolic compounds was observed by Vázquez *et al.* (1973); therefore, a correlation between stability and other variables involved in the oxidation process was sought. One direct correlation is found between stability and phenolic compounds ($r = 0.7378$) as well as an inverse one with linoleic acid concentration ($r = 0.6369$). There is a low inverse correlation with copper concentration ($r = 0.4530$) but none with iron and tocopherol contents.

The inverse relationship between stability and linoleic acid is due to the greater ease of oxidation of this acid, the most abundant polyunsaturated acid in olive oils. The relative rate of autoxidation of oleate:linoleate: linolenate was reported to be in the order of 40−50 and 100 times, respectively (Frankel, 1985). Therefore, it is suggested that the oxidative susceptibility (OS) of olive oils can be evaluated by means of the formula:

$$OS = m + 45L + 100Ln \qquad (1)$$

where m = % monounsaturated acids, L = % linoleic acid, and Ln = % linolenic acid.

From the different fatty acid composition of the oils from each olive cultivar arises a great variability of the oxidative susceptibility values (Table 4). Therefore, a new parameter, corrected stability (CS), is introduced in order to obtain a measurement of the stability related only with the oxidant and antioxidant agents in the oil. This parameter represents the theoretical stability of the oil if its fatty acid composition were equal to that of the less oxidizable olive oil. It is calculated by multiplying the Rancimat stability by the ratio between the oxidative susceptibility of the oil and that of the P_{II} oil ($m = 82.53\%$; $L = 2.55\%$; $Ln = 0.47\%$; OS $= 244.28$). This correction improves the correlation with phenols, increasing the coefficient r from 0.7378 to 0.8763 (Figure 1). Taking into account only the "three phase" oils, the correlation increases to 0.9270 (Figure 2) while the correlation observed in "two phase" oils is very low (0.3737). In Table 5, it can be seen that talc in "two phase" oils has a different effect on the stability than on the phenolic concentration. Consequently, in "three phase" oils, the stability depends mainly on the concentration of phenolic compounds, but in "two phase" oils other factors are important contributors. The deviations shown by some oils (Figures 1 and 2) can be attributed to the presence of polyphenols with different antioxidant activity, since this property is not measured by the analytical procedure. The correlation coefficient between copper and the corrected stability (CS) is similar to that with Rancimat ($r = 0.4530$ and 0.4130, respec-
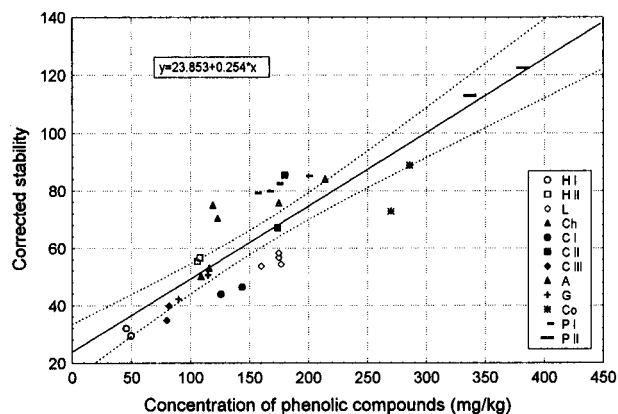
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Figure 1. Linear regression of phenolic compounds *vs* corrected stabilities in extra virgin olive oils. Stabilities are corrected with the relative oxidative susceptibilities of oils.
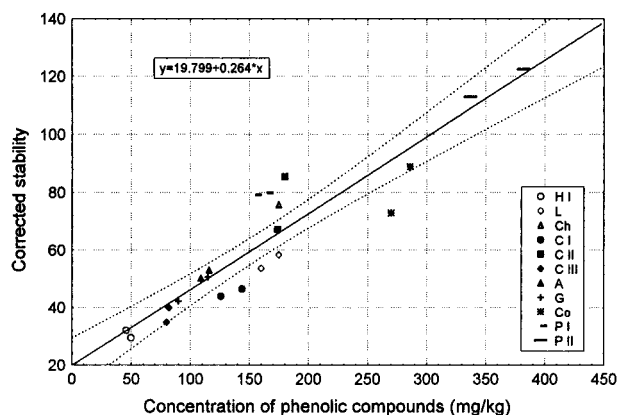

Figure 2. Linear regression of phenolic compounds *vs* corrected stabilities in extra virgin olive oils obtained by "three phase" centrifugation mode. Stabilities are corrected with the relative oxidative susceptibilities.

tively). There are no correlations of CS with iron and tocopherols.

From the above results, it can deduced that talc addition and centrifugation mode do not affect the quality variables of the oils, that is, acidity, peroxide index, K270, and K232. This is in agreement with our experience that, under the usual operating conditions, the oil quality depends mainly on the quality of the olive fruits just before milling. Nevertheless, "three phase" centrifugation involves a slight loss of phenolic concentration and stability, as compared to the "two phase" mode.

Addition of low percentages of talc during "two phase" centrifugation increases stability but does not increase phenolic compounds. On the contrary, the addition of talc at amounts greater than 2% during the "three phase" process causes slightly significant increases in stability and phenol concentrations. On the other hand, talc addition gives rise to a decrease in OxTGs. These facts suggest that talc facilitates the oil separation from the paste, reducing the oxidation during the obtention process. In the "three phase" process, there is a decrease in the talc effect by water dilution, and the loss of phenolic compounds is hindered.

LITERATURE CITED

Alba, J.; Muñoz, E.; Martínez, J. M. Obtention of Olive Oil. Use of Additives Facilitating its Extraction. *Alimentaria* **1982**, *138*, 25–55.

European Union Commission, Regulation EEC/2568/91 on the Characteristics of Olive and Olive Pomace Oils and on their Analytical Methods. Annex II: Determination of Acidity Value. Annex III: Determination of Peroxide Index. Annex IX: Spectrophotometric Test of UV Absorption. *Off. J. Eur. Commun.* **1991**, *L248*, 6–36. Regulation EEC/1429/92 on the Modifications to the Regulation EEC/2568/91. *Ibid.* **1992**, *L150*, 17–20. Regulation EEC/656/95 on the Modifications to the Regulation EEC/2568/91. *Ibid.* **1995**, *L69*, 1–5.

Frankel, E. N. Chemistry of Autoxidation: Mechanism, Products and Flavor Significance. In *Flavor Chemistry of Fats and Oils*; Min, D. B., Smouse, T. H., Eds.; American Oil Chemist's Society: Champaign, IL, **1985**; pp 1–37.

Gutfinger, T. Polyphenols in Olive Oils. *J. Am. Oil Chem. Soc.* **1981**, *58*, 966–968.

Gutiérrez, F. Determination of Oxidative Stability in Virgin Olive Oils: Comparison between Active Oxygen Method and Rancimat Method. *Grasas Aceites* **1989**, *40*, 1–5.

IUPAC. *Standard Methods for the Analysis of Oils, Fats and Derivatives. 7th Revised Edition and First Supplement*; Method Num. 2432, Determination of Tocopherols and Tocotrienols in Vegetable Oils and Fats by HPLC; Blackwell: Oxford, 1992.

Martín-Polvillo, M.; Albi, T.; Guinda, A. Determination of Trace Elements in Edible Vegetable Oils by Atomic Absorption Spectrophotometry. *J. Am. Oil Chem. Soc.* **1994**, *71*, 347–353.

Ministry of Health, Spain. Order of 13 January 1986. Approval of a Positive Register of Technological Additives to be used in the Elaboration of Edible Vegetable Oils. *Boletín Oficial del Estado* **1986**, *19*, 3089–3090.

Muñoz, E.; Alba, J.; Lanzón, A.; Aparicio, R. Report of the Experimental Oil Mill of the Instituto de la Grasa corresponding to the Season 1978–1979. *Grasas Aceites* **1979**, *30*, 251–261.

Muñoz, E.; Alba, J. Report of the Experimental Oil Mill of the Instituto de la Grasa corresponding to the Season 1979–1980. *Grasas Aceites* **1980**, *31*, 423–433.

Pérez-Camino, M. C.; García, J. M.; Castellano, J. M. Polar Compound Concentrations in Virgin Oils from Stored Cultivar Picual Olive Fruits. *J. Agric. Food Chem.* **1992**, *40*, 2260–2262.

Vázquez, A.; Janer, C.; Janer, M. L. Determination of Total Polyphenols in Olive Oils. *Grasas Aceites* **1973**, *24*, 350–357.