

## **Influence of malaxation time of olive paste on oil extraction yields and chemical and organoleptic characteristics of virgin olive oil obtained by a centrifugal decanter at water saving**

By **L. Di Giovacchino\***, **N. Costantini**, **M.L. Ferrante** and **A. Serraiocco**

Istituto Sperimentale per la Elaiotecnica - Viale Petruzzini, 37  
65013 Città S. Angelo (PE) - Italy

Phone number: 0039-085-95294/95212; Fax number: 0039-085-959518

E-mail address: elaiotec@unich.it

### **RESUMEN**

**Influencia del tiempo de batido de la pasta de aceitunas sobre los rendimientos en aceite y sobre la calidad química y organoléptica del aceite de oliva virgen obtenido con un decanter centrífugo con ahorro de agua.**

Se realizaron pruebas experimentales para verificar la influencia del tiempo de batido sobre los rendimientos en aceite y sobre las características de la calidad de los aceites obtenidos con un decanter centrífugo con ahorro de agua. Los resultados conseguidos indicaron que el tiempo de batido no debe ser inferior a 45 minutos para poder obtener rendimientos en aceite satisfactorios. Además, se pudo verificar que la operación de batido, aún siendo prolongada a 90 minutos, no influencia significativamente en las características cualitativas y organolépticas de los aceites. Sólo el contenido de fenoles totales en los aceites disminuyó cuando el tiempo de batido fue incrementado de 15 a 90 minutos. Sin embargo, se demostró que en algunos casos el contenido de fenoles totales en los aceites aumentó durante los primeros 15-45 minutos de batido mientras, sucesivamente, disminuyó de acuerdo con los resultados de la literatura. Esto se debe a la variación del contenido de fenoles totales en las aguas de vegetación que anteriormente aumentaron y luego disminuyeron. Debido a la ley del equilibrio de partición, también el contenido de los fenoles totales en sus correspondientes aceites varió de la misma manera. Finalmente, se hace notar que la composición de las sustancias volátiles del espacio de cabeza de los aceites no varía significativamente al variar el tiempo de batido de las pastas de aceitunas de buena calidad.

**PALABRAS-CLAVE:** *Aceite de oliva virgen - Batido de las pastas de aceitunas -Elaboración del aceite de oliva.*

### **SUMMARY**

**Influence of malaxation time of olive paste on oil extraction yields and chemical and organoleptic characteristics of virgin olive oil obtained by a centrifugal decanter at water saving.**

Experimental tests were carried out to ascertain the influence of malaxation time of olive paste on extraction yields and qualitative characteristics of virgin olive oils obtained by a centrifugal decanter at water saving. Results show that malaxation time has to be no less than 45 minutes to have a satisfactory oil extraction yield. Furthermore, it was ascertained that the malaxation time, protracted up to 90 minutes, does not have influence upon qualitative and organoleptic characteristics of oils. Only the total phenols content of oils changed significantly when the malaxation time of olive paste increased from 15 to 90 minutes. However, in this research has been demonstrated that in some cases the total phenols content of oils increased during the first 30-45 minutes of malaxation and after it diminished. This is

due to the variation of total phenols content of vegetable water that in the first time increased and after diminished very quickly. Because of the partition equilibrium law, the total phenols content of oil changed in the same way. Finally, results show that the composition of volatile substances of head-space of oils did not change increasing the malaxation time of olive paste obtained from good quality olive fruits.

**KEY-WORDS:** *Malaxation of olive paste - Olive processing - Virgin olive oil.*

### **1. INTRODUCTION**

Olive processing by mechanical systems (pressure, percolation, centrifugation) needs the malaxation of olive paste to increase the extraction yields. The malaxation is an useful technological operation that entails stirring the olive paste slowly and continuously to favour the droplets of oil to merge into large drops (Martinez Moreno *et al.*, 1957), that can be separated into a continuous liquid phase ("free oil") extractable by pressure (Di Giovacchino *et al.*, 1984-87), by percolation (Di Giovacchino *et al.*, 1988), and centrifugation systems (Vitagliano *et al.*, 1972; Di Giovacchino, 1991).

The use of metallic crusher to crush olives, because of its violent action, generally causes an emulsion of olive paste that reduces oil yields. To avoid or cut down the emulsion state, it needs to increase the malaxation time and, in some cases, the malaxation temperature also (Solinas *et al.*, 1978). This may cause a negative influence on the qualitative characteristics of virgin olive oil because of the activity of the enzymes, naturally present in the olive paste, which may develop affecting the percentage of free fatty acids content, peroxide value and phenol content of oil.

The reduction of natural antioxidants content (Solinas *et al.*, 1978; Di Giovacchino, 1991; Servili *et al.*, 1992; Servili *et al.*, 1994; Montedoro *et al.*, 1994; Amirante *et al.*, 1995; Hermoso *et al.*, 1996; Alloggio *et al.*, 1996; Lercker *et al.*, 1999; Cert *et al.*, 1999) and the variation of the volatile substances composition (Angerosa *et al.*, 1998; Lercker *et al.*, 1999) of oil obtained from olive paste longer mixed,

can be dangerous for oil containing less quantity of these substances due to natural causes (variety) or to water added during the extraction process with the conventional decanter, called at 3 phases (Di Giovacchino *et al.*, 1994a, c), that requires 50-70 liters of lukewarm water added to 100 kg of olive paste.

At begins of '90s, new centrifugal decanters were launched on the market with the end to reduce the quantity of water added to olive paste (Di Giovacchino *et al.*, 1994 b). Actually the centrifugal decanters utilized in olive oil mills, in Italy and in other countries, are the following : i) centrifugal decanter at 3 phases, type conventional : it operates by adding 50-70 liters of lukewarm water per 100 kg of olive paste, and separates oil, pomace (45-55% of moisture) and vegetable water (70-90 L/100 kg of olives) by 3 flow exits; ii) centrifugal decanter at 2 phases, type integral: it operates without adding lukewarm water to olive paste and separates oil and pomace (65-72% of moisture) by 2 flow exits only; iii) centrifugal decanter at 3 phases, type "water saving": it operates by adding 0-20 liters of lukewarm water per 100 Kg of olive paste, and separates oil, pomace (55-60% of moisture) and vegetable water (5-30 L/100 kg olives) by 3 flow exits.

All types of centrifugal decanters have the possibility to give a good oil yields if the olive paste is fairly mixed and for this the malaxation operation is very important for the quality of oil.

In this paper, the influence of malaxation time on extraction yields, qualitative characteristics, total natural antioxidants content and composition of volatile compounds of oils obtained by the new centrifugal decanter at water saving is studied. In addition, the coefficient of partition of total phenols between oil and vegetable water is calculated.

## 2. EXPERIMENTAL PROCEDURES

Olive oil extraction tests by centrifugation system were performed during olive harvest season, using a new centrifugal decanter, manufactured by Rapanelli S.p.A., Foligno, Italy.

This decanter, type 4500-S and called at water saving, has the possibility to separate oil from the pomace and vegetable water using a small quantity of lukewarm water added to olive paste.

Tests were carried out using different cultivars of olives (Dritta 1; Mixed varieties 1; Leccino; Dritta 2; Mixed varieties 2), picked on November and processed following the working diagram reported in the Figure 1. After leaf-removal and washing, an homogeneous lot of kg 1,600 of olives of each cultivar was utilized. This quantity was divided in four batches, each one of 400 kg, and utilized in this way: the first batch was used to make ready the machinery and other three batches for the tests at

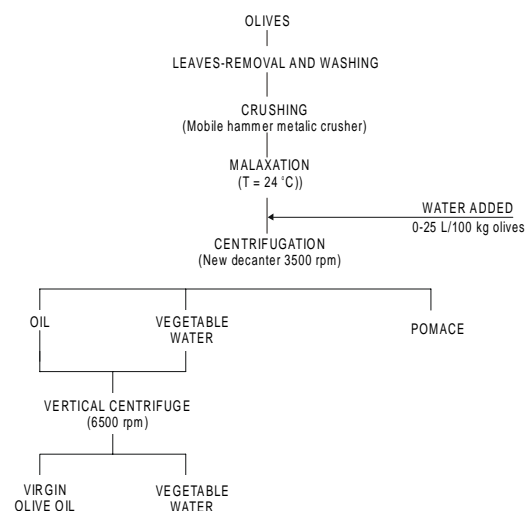


Figure 1  
Diagram of olive processing by new centrifugal decanter called at water saving.

different times of malaxation. Each batch of olives was crushed by a mobil hammer metal crusher and the olive paste obtained was mixed at 24°C for 0, 30 and 75 minutes in the first sep of malaxation. Then, olive paste was poured in the homogenizer (2nd step of malaxation) and immediately centrifuged in the above mentioned centrifugal decanter at water saving loaded with 800 kg/h of olive paste and with addition of 0-25 L of water at 24°C per 100 kg of olive paste.

Being 15 minutes the average time of the malaxation of olive paste in the homogenizer, the total times of malaxation (1st step + 2nd step) were: 15 (0'+15'), 45 (30'+15') and 90 (75'+15') minutes.

Oil was separated from the oily must (olive oil + vegetable water) by an automatic discharge vertical centrifuge, without addition of clean water.

To estimate the oil yields of the olive processing, the weight of olive fruits and pomace and the volume of vegetable water were determined. Oil extraction yields have been also calculated as the percentage of oil extracted by industrial centrifugal decanter (kg/100 kg olives) and oil content (kg/100 kg olives) of olive fruits measured by Soxhlet apparatus.

On olive fruits and pomace samples were determined:

- moisture content, in oven at 105°C; oil content, by Soxhlet apparatus, using petroleum ether 40-60°C.

On vegetable water samples were determined:

- dry matter, in oven at 105 °C; oil content, by Soxhlet apparatus (Di Giovacchino, 1986); total phenol content (Singleton *et al.*, 1965), expressed as gallic acid.

On olive oil samples were determined:

Table I  
Influence of malaxation time on technological results obtained processing olive paste of different cultivars by the new centrifugal decanter at water saving

OLIVES			Malaxation time (min)	Oil extraction yield %	POMACE				VEGETABLE WATER			
Cultivar	Moisture %	Oil %			Quantity %	Moisture %	Oil %	Oil kg/100 kg olives	Quantity % v/w	Dry matter %	Oil g/L	Oil kg/100 kg olives
Dritta 1	48.8	23.1	15	82.7	70.2	58.6	4.1	2.9	8	16.5	33.5	0.3
	"	"	45	84.8	71.6	59.8	3.6	2.6	7	16.4	23.1	0.2
	"	"	90	88.8	69.7	61.6	3.0	2.1	8	15.5	16.1	0.1
Mixed 1 cvrs.	48.0	21.0	15	77.8	82.5	57.2	5.4	4.5	1	15.2	18.4	--
	"	"	45	80.2	81.3	57.7	4.8	3.9	2	15.0	14.3	--
	"	"	90	83.3	81.8	59.4	3.9	3.2	1	15.8	14.8	--
Leccino	54.5	14.2	15	75.2	65.2	57.3	4.0	2.3	43	14.1	17.8	0.8
	"	"	45	80.0	65.2	57.7	3.3	2.0	37	15.6	14.8	0.6
	"	"	90	83.8	62.3	56.7	2.9	1.8	38	16.3	9.3	0.4
Dritta 2	48.7	22.3	15	79.4	64.4	57.1	4.8	3.1	34	12.5	33.0	1.0
	"	"	45	84.8	65.2	57.5	3.6	2.3	26	12.8	27.0	0.8
	"	"	90	86.9	65.9	57.5	3.2	2.1	26	12.1	16.2	0.5
Mixed 2 cvrs.	45.5	21.4	15	77.6	76.1	58.3	3.8	2.9	40	10.5	35.1	1.4
	"	"	45	84.0	76.6	58.1	3.0	2.3	29	12.4	28.4	0.8
	"	"	90	85.5	78.0	59.7	2.6	2.0	25	12.9	24.6	0.6

- free fatty acids (%), peroxide value (m.eq. O<sub>2</sub>/kg), specific spectrophotometric absorptions in the UV region and organoleptic assessment (score) (EEC Rule, 1991);
- total phenol content (Ragazzi *et al.*, 1973), expressed as gallic acid;
- induction time (hour), measured by Rancimat 679 apparatus (Laubli *et al.*, 1986), at 120°C and with an air flow of 20 L/h;
- chlorophyll pigments (Wolff, 1968);
- the composition of volatile substances after stripping the oil with nitrogen at 37°C for 2 hours (Camera *et al.*, 1990). The volatile substances were adsorbed on active carbon and then transferred into test-tubes containing 1 ml of diethyl ether. The solution thus obtained was injected on column into gas-chromatograph (type HRGC 5160 Mega series, Carlo Erba Instruments S.p.A., Rodano, Italy) fitted with a fused silica capillary GC column (NB 20 M, 50 m x 0.32 mm, film thickness 0.50 µm, HNU-Nordion Ltd, Helsinki, Finland) using hydrogen as the carrier gas. Temperature program varying from 25 to 155 °C, with a FID detector at 180 °C, was used. The identification of components was carried out by comparison of RRT of standard components following the same conditions reported in other paper (Camera *et al.*, 1990). The concentration of each component was determined by using 1-nonanol as internal standard.

The results obtained were tested by *t* or ANOVA tests.

### 3. RESULTS AND DISCUSSION

Table I shows the influence of malaxation time of olive paste on oil yields and by-products characteristics obtained processing 5 different olive varieties by centrifugal decanter at water saving. Table II shows the average values of the same results statistically treated (test *t*).

Oil yields significantly increased when malaxation time changed from 15 to 45 and 90 minutes, in agreement with results reported in other papers (Vitagliano *et al.*, 1972; Di Giovacchino *et al.*, 1984-87; Di Giovacchino, 1991). The quantity of oil mechanically extractable by the centrifugation system depends from the quantity of free oil present in the olive paste after crushing and malaxation operations.

Olive crushing by metallic hammer crusher, generally, determines an emulsion that it is possible to reduce only by the malaxation, carried out for 45 minutes at least, in relation to the olive characteristics. When the malaxation time was 15 minutes, the oil yield was very low, especially for some olive cultivars, difficult to process, as shown in the Figure 2.

The different oil yields are due to the different quantity of oil lost in the by-products (pomace and vegetable water), obtained processing olive paste by the centrifugal decanter. The average quantity of oil lost in the pomace changed from 3.1 to 2.2 kg/100 kg olives, when the malaxation time increased from 15 to 90 minutes, as shown in Table II, in agreement with the results reported in other paper (Hermoso *et*

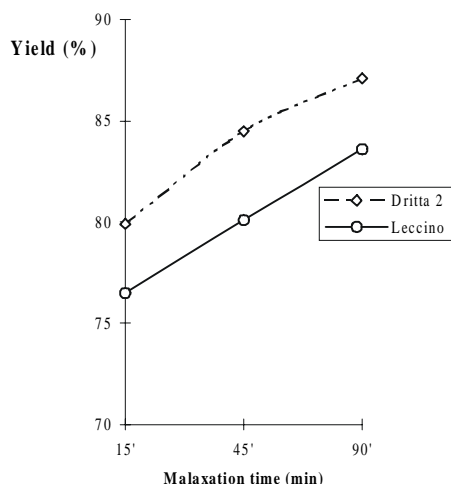


Figure 2  
Influence of malaxation time of olive paste with different rheological characteristics, on oil extraction yields obtained by the centrifugal decanter at water saving.

*al.*, 1996). The average quantity of oil lost in vegetable water changed from 0.7 to 0.3 kg/100 kg olives, when the malaxation time increased from 15 to 90 minutes, as shown in the same Table II. Finally, the total oil lost in the by-products was, on average, 3.8 and 2.5 kg/100 kg olives (statistically significant difference), when the malaxation time changed from 15 to 90 minutes.

This confirms that the malaxation time of olive paste is important to have good yields and for this it has to be no lower than 45 minutes, when olives are processed by centrifugal decanter, as reported in other paper (Di Giovacchino, 1991).

Results obtained in the analysis of virgin olive oil samples are shown in Table III and in Table IV, where

Table II  
Average technological results obtained by the centrifugal decanter at water saving from olive paste of different cultivars mixed for different times

DETERMINATIONS	MALAXATION TIME (min)		
	15	45	90
Oil extraction yield (%)	78.5 a	82.8 b	85.7 b
<u>Olive pomace</u>			
Quantity (kg/100 kg olives)	71.7 a	71.9 a	71.5 a
Moisture (% on fresh pomace)	57.7 a	58.2 a	58.9 a
Oil (% on fresh pomace)	4.4 a	3.6 ab	3.1 b
Oil (kg/100 kg olives)	3.1 a	2.6 a	2.2 a
<u>Vegetable waste water</u>			
Quantity (L/100 kg olives)	25 a	20 a	20 a
Dry matter (% on fresh vww )	13.8 a	14.4 a	14.5 a
Oil (% on fresh vww)	2.8 a	2.1 a	1.6 a
Oil (kg/100 kg olives)	0.7 a	0.5 a	0.3 a
Total oil lost in by-products (kg/100 kg olives)	3.8 a	3.1 ab	2.5 b

Different letters indicate a statistically significant difference  $P < 0.05$  (test t).

the average results, statistically treated, are also reported. The values of free fatty acids percentage, peroxide number, specific spectrophotometric absorptions in the UV region and organoleptic assessment of oils, obtained changing the malaxation time, are not statistically different. This means that oils, obtained from good quality olives by centrifugal decanter after a 15-90 minutes of

Table III  
Influence of malaxation time on the qualitative characteristics of virgin olive oils obtained processing olive paste of different cultivars by the centrifugal decanter at water saving

Olive cultivar	Malaxation time min	Free fatty acids %	Peroxide value meqO <sub>2</sub> /kg	K <sub>232</sub>	K <sub>270</sub>	Organoleptic assessment score	Total phenols mg/l (gallic acid)	Induction time h	Chlorophyll pigments ppm
Dritta 1	15	0.41	4.8	1.53	0.13	7.0	415	16.8	5.8
	45	0.39	3.8	1.49	0.12	7.2	401	16.3	5.6
	90	0.42	4.5	1.54	0.12	7.0	377	15.6	5.7
Mixed cvrs.1	15	0.43	5.5	1.58	0.10	7.1	240	12.8	6.0
	45	0.39	6.6	1.64	0.11	7.2	230	12.0	6.1
	90	0.41	5.8	1.62	0.11	7.3	181	10.9	5.5
Leccino	15	0.31	4.5	1.49	0.10	7.4	285	14.6	5.6
	45	0.28	4.1	1.50	0.11	7.3	306	14.6	5.5
	90	0.30	4.0	1.51	0.11	7.3	265	13.6	5.6
Dritta 2	15	0.65	7.3	1.54	0.14	7.2	250	10.0	6.0
	45	0.78	7.1	1.50	0.12	7.2	238	9.8	6.6
	90	0.67	7.5	1.51	0.12	7.2	196	9.2	6.4
Mixed cvrs 2	15	0.28	4.8	1.38	0.10	7.3	154	10.2	6.1
	45	0.31	5.0	1.44	0.11	7.2	159	9.9	5.9
	90	0.25	4.9	1.38	0.09	7.1	106	8.4	6.0

Table IV  
Average values of qualitative characteristics of virgin olive oils obtained by the centrifugal decanter at water saving from olive paste of different cultivars mixed for different times

DETERMINATIONS	Malaxation time (min)		
	15	45	90
Free Fatty acids (% oleic ac.)	0.42 a	0.43 a	0.41 a
Peroxide value (m.eq.O <sub>2</sub> /kg)	5.4 a	5.3 a	5.3 a
K <sub>232</sub>	1.50 a	1.51 a	1.51 a
K <sub>270</sub>	0.11 a	0.11 a	0.11 a
Organoleptic assessment (score)	7.2 a	7.2 a	7.2 a
Total phenols (gallic ac. mg/l)	269 a	267 a	225 b
Induction time (h)	12.9 a	12.5 a	11.5 a
Chlorophyllic pigments (ppm)	5.9 a	5.9 a	5.8 a

Different letters indicate a statistically significant difference ( $P < 0.05$ , ANOVA test).

malaxation, have the same qualitative characteristics and, in particular, the same, low degree of oxidation (peroxide value, K<sub>232</sub>, K<sub>270</sub>).

This is due to the protective action of the great mass of olive paste utilized in the industrial tests. In these conditions, during the malaxation, only a little part of olive paste is exposed to the air and may be oxidized, but other large part is protected from the oxidation and oil cannot change its chemical characteristics in the short time of malaxation operation.

The total phenol content only significantly diminished (ANOVA test) when the malaxation time increased from 15 to 90 minutes, in agreement with the results reported in other papers, before named.

As reported in Table IV, the total phenol content of oils, obtained from olive paste mixed for 15 and 90 minutes, was, on average, 269 and 225 mg/L, with a 16% of reduction. This small difference is normal when tests are carried out with industrial plants and large quantity of olive paste is mixed for different times. In this case, only the superficial layer of olive paste (a very small percentage), and relative phenolic compounds, is exposed to air and to oxidation, whereas a large part is covered and effectively protected by the reducing conditions due to the antioxidant properties of phenolic substances present in large quantity.

When the same tests are carried out using small quantity of olive paste (1-10 Kg) and small laboratory plants, it is possible to have oils with a higher difference of total phenol content. This happens

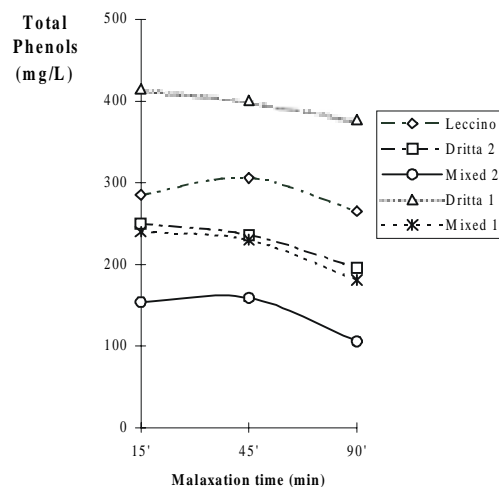


Figure 3  
Influence of malaxation time on total natural phenols content of virgin olive oils obtained by centrifugal decanter from different olive varieties.

because the superficial layer of olive paste exposed to air and oxidized represents a high percentage of total paste. This causes a remarkable reduction of total phenol content of olive paste, vegetable water and oil, as reported in other papers (Servili *et al.*, 1992; Servili *et al.*, 1994; Montedoro *et al.*, 1994; Lercker *et al.*, 1999).

In particular, in this research, it was observed that, in some industrial tests, the total phenol content rose when the malaxation time changed from 15 to 45 minutes, as shown in the Figure 3. This phenomenon was unexpected, and to have a confirmation, the total phenol content of vegetable waters was determined.

Results show that, at beginning of malaxation, the phenol content of vegetable water rose, and after it diminished, as reported in the Figure 4. This is

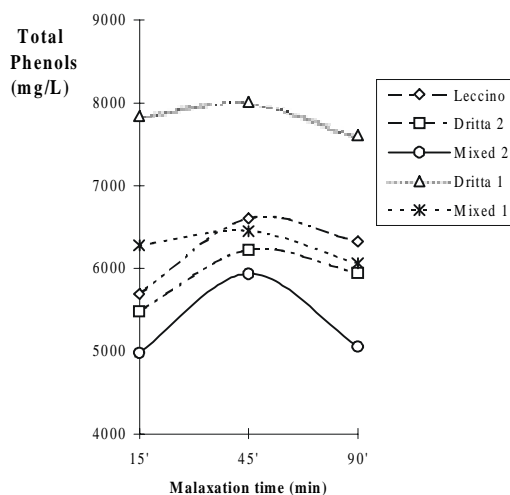


Figure 4  
Influence of malaxation time on total natural phenols content of vegetable waters obtained by centrifugal decanter from different olive varieties.



probably due to the crushing operation carried out by the mobile hammer metallic crusher, that operates quickly and not very violently determining a partial breakage of the cells of the olive flesh. The observed phenomenon, in fact, does not happen when olives are crushed slowly by the granite millstone, that takes 20-30 minutes to grind fairly olives, as reported in other paper (Solinas *et al.*, 1978).

The variation of phenol content of oils and corresponding vegetable waters, during the malaxation step, can be explained in this way: (i) at beginning of the operation, the slow movement of the olive paste favours the breakage of the cellular structure of the flesh, by enzymatic and mechanical actions, and a part of phenolic substances, bound with other chemical compounds to form complex structures (Wallace *et al.*, 1994), liberates phenolic glycosides soluble in the aqueous phase. This causes the increment of total phenol content of vegetable water; (ii) a part of phenolic glycosides, containing tyrosol and hydroxytyrosol, hydrolyses liberating the corresponding aglycones, more soluble in the oily phase. This causes, in some case, the increment of total phenol content of oils, during the first time of malaxation.

Increasing the malaxation time, the total phenol content of vegetable water diminishes because of the oxidative activity of phenoloxydase enzymes (Ragazzi *et al.*, 1967). This causes the reduction of phenol content of oils also, in agreement with the results reported in other before named papers, because of the law of partition equilibrium of phenolic compounds between oily and aqueous phases.

The partition equilibrium is expressed from the ratio of the concentrations of a chemical compound in two immiscible liquids in contact, as the following equation:

$$K = [A]_{\text{aqueous phase}} / [A]_{\text{oily phase}}$$

where: K is the constant of partition equilibrium; [A] is the concentration of the compound A, expressed as mol/L.

The value of K, in conditions of chemical-physical equilibrium, depends from the temperature only and, therefore, it is constant at constant temperature.

The results obtained in this research, changing the malaxation time of olive paste, indicated that the ratio values of total phenol content in vegetable water and oil of the same olive varieties were sensibly constant, as shown in the Figure 5. The differences of the K values are not statistically significant and indicate that a satisfactory equilibrium is reached between the immiscible liquid phases in contact and quickly rotating into the centrifugal decanter (speed = 3,600 r/min).

Because of the invariance of the K value, at constant temperature, when the total phenol content of vegetable water diminishes, the total phenol

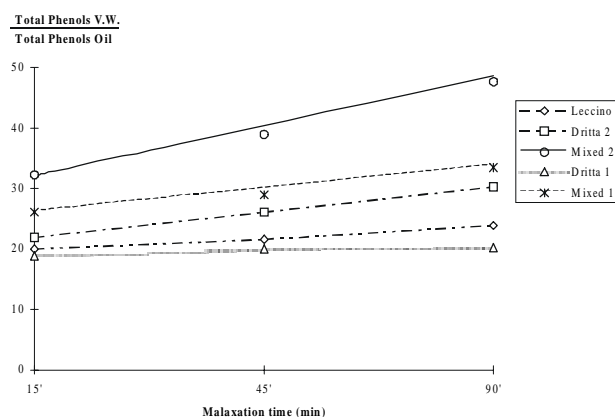


Figure 5  
Experimental values of the ratio (K) of total phenol content of vegetable water and oil obtained by centrifugal decanter from olive pastes mixed for different times.

content of oil is also decreasing (Welsh *et al.*, 1989; Di Giovacchino *et al.*, 1994 b, c; Bianchi, 1999).

Table V shows the results obtained in the determination of volatile substances present in the headspace of virgin olive oils. The average values, reported in Table VI, indicate that the content of each volatile compound did not vary significantly when the malaxation time of olive paste increased from 15 to 90 minutes, while a significant difference ( $P < 0.05$  with ANOVA test) was ascertained for total volatile substances content only. This means that several volatile compounds, especially those naturally present in virgin olive oil and derived from the enzymatic decomposition of 13-L-hydroperoxide of the linolenic and linoleic acids (Olias *et al.*, 1993), are formed in a short time, soon after olive crushing and the cells of the pulp are broken. Then, protracting the malaxation time up to 90 minutes at the temperature of 24°C, the content of each compound generally increases, but in not significant way, in partial agreement with the results obtained in other tests carried out by laboratory little plants (Angerosa *et al.*, 1998; Lercker *et al.*, 1999).

It is important, however, that the content of some volatile compounds, as n-octane, iso-amyl alcohol, iso-butyl alcohol, acetic acid and ethyl acetate, responsible of specific off-flavors of oils (fusty and winey), did not vary significantly when the malaxation time of olive paste increased up to 90 minutes. This happens because the enzymatic activity of microorganismes (Angerosa *et al.*, 1996), present in the olive paste, cannot develop during the normal time of malaxation (45-90 minutes) so much to make possible the formation of the above mentioned substances. For this, all oils obtained in this present research had good organoleptic properties, as ascertained from the tasters.

Table V

**Volatile substances content (mg/kg) of head-space of oils obtained by the centrifugal decanter at water saving from olive pastes of different cultivars mixed for different times at 24 °C**

VOLATILE COMPOUNDS (mg/kg)	Dritta 1			Mixed cvrs. 1			Leccino			Dritta 2			Mixed cvrs. 2		
	15'	45'	90'	15'	45'	90'	15'	45'	90'	15'	45'	90'	15'	45'	90'
n-Octane	4	3	2	3	3	4	5	5	8	15	27	26	2	2	4
Ethyl acetate	2	2	3	3	6	3	8	10	7	5	5	5	6	12	9
2-Methyl-butanol	2	3	3	6	3	6	12	15	21	1	3	2	3	4	5
3-Methyl-butanol	2	1	4	6	3	7	13	15	21	1	2	2	4	5	4
Ethyl alcohol	41	41	42	44	43	43	33	37	35	24	23	25	32	31	33
Pentan-3-one	14	24	23	18	17	14	14	24	21	19	26	28	11	11	12
1-Penten-3-one	25	35	49	22	23	25	13	14	16	9	9	9	11	11	10
Hexanal	22	20	33	32	25	32	14	13	17	25	33	35	21	17	14
iso-Butyl alcohol	2	3	4	17	17	18	4	6	7	10	14	12	3	3	4
trans-2-Pentenal	2	4	4	2	2	2	2	2	2	2	3	2	2	2	2
1-Penten-3-ol	22	34	43	25	27	29	14	15	17	18	22	20	15	15	12
iso-Amyl alcohol	5	6	7	38	33	38	8	15	16	15	18	19	14	14	14
trans-2-Hexenal	219	233	258	265	263	280	399	360	397	376	362	353	250	274	258
n-Amyl alcohol	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1
2-Penten-1-ol	13	19	22	9	7	10	7	8	9	11	12	12	6	7	6
1-Hexanol	7	9	9	11	10	12	6	18	17	23	25	32	6	7	11
cis-3-Hexen-1-ol	4	6	7	6	4	7	2	2	2	4	6	4	3	4	5
trans-2-Hexen-1-ol	12	16	16	7	6	7	25	41	59	43	48	59	7	8	17
Acetic acid	1	5	3	1	2	3	4	4	2	1	6	8	1	1	1
1-Octanol	4	4	4	5	4	3	1	1	1	1	1	1	1	1	1
TOTAL VOLATILE COMPOUNDS	404	469	537	521	499	544	583	606	677	605	648	656	399	431	422

Table VI

**Average content (mg/kg) of volatile substances of oils obtained by centrifugal decanter at water saving from olive pastes of different cultivars mixed for different times**

VOLATILE COMPOUNDS (mg/kg)	Malaxation time (min)		
	15'	45'	90'
n-Octane	5.8 a	8.0 a	8.8 a
Ethyl acetate	4.8 a	7.0 a	5.4 a
2-Methyl butanol	4.8 a	5.6 a	7.4 a
3-Methyl-butanol	5.2 a	5.2 a	7.6 a
Ethyl alcohol	34.8 a	35.0 a	35.6 a
Pentan-3-one	15.2 a	20.4 a	19.6 a
1-Penten-3-one	16.0 a	18.4 a	21.8 a
Hexanal	22.8 a	21.6 a	26.2 a
iso-Butyl alcohol	7.2 a	8.6 a	9.0 a
trans-2-Pentenal	2.0 a	2.6 a	2.4 a
1-Penten-3-ol	18.8 a	22.6 a	24.2 a
iso-amyl alcohol	16.0 a	17.2 a	18.8 a
trans-2-Hexenal	301.8 a	298.4 a	309.2 a
n-Amyl alcohol	1.2 a	1.2 a	1.4 a
2-Penten-1-ol	9.2 a	10.6 a	11.8 a
1-Hexanol	10.6 a	13.8 a	16.2 a
cis-3-Hexen-1-ol	3.8 a	4.4 a	5.0 a
trans-2-Hexen-1-ol	18.8 a	23.2 a	31.6 a
Acetic acid	1.6 a	3.6 a	3.4 a
1-Octanol	2.4 a	2.2 a	2.0 a
TOTAL VOLATILE COMPOUNDS	502.4 a	530.6 ab	567.2 b

Different letters indicate a statistically significant difference ( $P < 0.05$ , ANOVA test).

## REFERENCES

Alloggio, V., Caponio, F. and De Leonardis, T. (1996). Influenza delle tecniche di preparazione della pasta di olive sulla qualità dell'olio. Nota I: profilo quali-quantitativo delle sostanze fenoliche, mediante

- HPLC, in olio d'oliva vergine della cv Ogliarola Salentina. *Riv. Ital. Sost. Grasse*, **73**, (8), 355-360.
- Angerosa, F., Lanza, B. and Marsilio, V. (1996). Biogenesis of "fusty" defect in virgin olive oils. *Grasas y Aceites*, **47**, (3), 142-150.
- Angerosa, F., D'Alessandro, N., Basti, C. and Vito, R. (1998). Biogenesis of volatile compounds in virgin olive oil: their evolution in relation to malaxation time. *J. Agric. Food Chem.* **46**, 2940-2944.
- Amirante, P., Colelli, G. y Greco, L. (1995). Valutazione degli aspetti produttivi e qualitativi degli impianti di estrazione olearia in Provincia di Lecce. *Atti del Seminario di Studio della II e VI Sezione Tecnica dell'A.I.I.A.*, p. 347-359. Selva di Fasano (I), 20-23 Settembre.
- Bianchi, G. (1999). Extraction systems and olive oil. *O C L*, **6**, (1), 49-55.
- Camera, L. y Solinas, M. (1990). Identificazione di alcune sostanze aromatiche degli oli di oliva mediante GLC-MS. *Proceedings of International Seminary "Olio di Oliva e Olive da Mensa: Tecnologia e Qualità"*, p. 153-168. Città S. Angelo (I), April, 25-28.
- Cert, A., Alba, J., Perez-Camino, M.C., Ruiz-Gomez, A., Hidalgo, F., Moreda, W., Moyano, M.J., Martinez, F., Tubaileh y R., Olías, J.M. (1999). Influenza dei sistemi di estrazione sulle caratteristiche e sui composti minori dell'olio d'oliva vergine extra. *OLIVAE*, **79**, 41-50.
- Di Giovacchino, L. (1986). La determinazione dell'olio contenuto nelle acque di vegetazione delle olive. *Riv. Ital. Sost. Grasse*, **63**, (4), 203-207.
- Di Giovacchino, L. y Solinas, M. (1984-87). Incidenza della frangitura delle olive e della granulazione delle paste sui rendimenti di estrazione dell'olio con il sistema della pressione. *Ann. Ist. Sper. Elaiotecnica*, **X**, 201-208.
- Di Giovacchino, L. y Mascolo, A. (1988). Incidenza delle tecniche operative nell'estrazione dell'olio dalle olive con il sistema continuo. Nota II. *Riv. Ital. Sost. Grasse*, **65**, (4), 283-289.
- Di Giovacchino, L. (1991). L'estrazione dell'olio con la centrifugazione diretta delle paste di olive. Nota I:

- influenza della gramolazione. *Riv. Ital. Sost. Grasse*, **68**, (8), 413-420.
- Di Giovacchino, L., Solinas, M. and Miccoli, M. (1994a). Effect of extraction systems on the quality of virgin olive oil. *J. Am. Oil Chem. Soc.* **71**, (11), 1189-1194.
- Di Giovacchino, L., Costantini, N. y Di Febo, M. (1994b). La centrifugazione delle paste di olive senza acqua di diluizione. *Riv. Ital. Sost. Grasse*, **71**, (11), 555-559.
- Di Giovacchino, L., Solinas, M. y Miccoli, M. (1994c). Aspetti qualitativi e quantitativi delle produzioni olearie ottenute dalla lavorazione delle olive con i differenti sistemi di estrazione. *Riv. Ital. Sost. Grasse*, **71**, (12), 587-594.
- EEC Rule 2568/91 (1991). *Gazzetta Ufficiale* **248** del 5 Settembre 1991.
- Hermoso, M.J., Gonzalez Delgado, J., Uceda Ojeda, M., Garcia-Ortiz Rodriguez, A., Morales Bernardino, J., Frias Ruiz, L. y Fernandez Garcia, A. (1996). Elaboracion de aceite de oliva de calidad. Obtencion por el sistema de dos fases. 3<sup>a</sup> edicion. *Junta de Andalucia*, Sevilla (Spain).
- Laubli, M.V. and Bruttel, P. (1986). Determination of oxidative stability of fats and oils: comparison between the Active Oxygen Method (AOCS Cd 12-57) and the Rancimat Method. *J. Am. Oil Chem. Soc.* **63**, (6), 792-795.
- Lercker, G., Frega, N., Bocci, F. and Mozzon, M. (1999). Volatile constituents and oxidative stability of virgin olive oils: influence of the kneading of olive-paste. *Grasas y Aceites*, **50**, (1), 26-29.
- Martinez Moreno, J.M., Gomez Herrera, C. y Janer del Valle, C. (1957). Estudios fisico-químicos sobre las pastas de aceituna molidas. IV. Las gotas de aceite. *Grasas y Aceites*, **8**, 112-120.
- Montedoro, G.F., Servili, M. y Baldioli, M. (1994). Lo stato di dispersione colloidale delle paste di olive e le implicazioni sulle caratteristiche compositive dell'olio. *Atti del Convegno "Le centrifughe a 2 fasi nell'estrazione dell'olio di oliva : problematiche, prospettive qualitative e implicazioni della utilizzazione dei sottoprodotti"*, p. 21-42. Spoleto (I), 28 Ottobre.
- Olias, J.M., Perez, A.G., Rios, J.J. and Sanz, L.C. (1993). Aroma of virgin olive oil: biogenesis of the "green" odor notes. *J. Agric. Food Chem.* **41**, 2368-2373.
- Ragazzi, E., Veronese, G. y Pietrogrande A. (1967). Ricerche sui costituenti idrosolubili delle olive. Nota II : pigmenti e polisaccaridi. *Annali di Chimica*, **57**, 1398-1413.
- Ragazzi, E. and Veronese, G. (1973). Research on the phenolic components of olive oils. *Riv. Ital. Sost. Grasse*, **50**, (12), 443-452.
- Servili, M., Baldioli, M. y Montedoro, G.F. (1992). I Meccanismi che influenzano la concentrazione in polifenoli dell'olio vergine di oliva. *Proceedings of International Congress "Olive Oil Quality"*, p. 375-376. Firenze (I), 1-3 Dicembre.
- Servili, M., Baldioli, M. and Montedoro, G.F. (1994). Phenolic composition of virgin olive oil in relationship to some chemical and physical aspects of malaxation. *Acta Horticulturae. Olive Growing II*, **356**, 331-336.
- Singleton, V.L. and Rossi, J.R. (1965). Colorimetry of total phenolic with phosphomolibdic-phosphotungstic acid reagent, *Am. J. Enol. Vitic.* **16**, 144-148.
- Solinas, M., Di Giovacchino, L. y Mascolo, A. (1978). I polifenoli delle olive e dell'olio d'oliva. Nota III: influenza della temperatura e della durata della gramolazione sul contenuto di polifenoli degli oli. *Riv. Ital. Sost. Grasse*, **55**, (1), 19-23.
- Vitagliano, M. and Radogna, V.M. (1972). Perspectives de la technologie oléicole. *Informations Oléicoles Internationales*, **58-59**, 73-79.
- Wallace, G. and Fry, S.C. (1994). Phenolic compounds of the plant cell wall. *Int. Rev. Cytol.* **151**, 229-267.
- Welsh, F.W. and Williams, R.E. (1989). The use of vegetable oils to recover compounds from aqueous solutions. *J. Chem. Tech. Biotechnol.* **46**, 169-178.
- Wolff, J.P. (1968). *Manuel d'Analyse des Corps Gras*. Edited by Azoulay Editeur, Paris.

Recibido: Febrero 2001  
Aceptado: Julio 2001