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Characterization of Sicilian virgin olive oils. Note X. A comparison between *Cerasuola* and *Nocellara del Belice* varieties

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RESUMEN

Caracterización de aceites de oliva Sicilianos. Nota X. Una comparación entre las variedades *Cerasuola* y *Nocellara del Belice*.

Un noventa por ciento de los olivos de la cuenca mediterránea son destinados a la producción de aceite. Dentro de un amplio estudio de los aceites de oliva del sur de Italia, con especial atención a Sicilia, se han estudiado distintas variedades de olivos. El resultado de un estudio analítico llevado a cabo con dos cultivares "*Nocellara del Belice*" y "*Cerasuola*" es descrito en este trabajo. Se muestran distintos parámetros relacionados con la pureza del aceite y la estabilidad junto con la composición (%) esterólica y de ácidos grasos de los ácidos individuales. Los datas obtenidos se analizan tanto por métodos paramétricos univariantes (test de Mann-Whitney) como por procedimientos multivariantes de análisis factorial.

PALABRAS-CLAVE: Aceite de oliva - Calidad - Caracterización - Variedad.

SUMMARY

Characterization of Sicilian virgin olive oils. Note X. A comparison between *Cerasuola* and *Nocellara del Belice* varieties.

Ninety percent of the olive trees are destined to oil production in the Mediterranean basin. Within a wide study of Southern Italian olive oils, with a particular reference to Sicily, several varieties of olive have been studied. The result of an analytical study carried out with two cultivars "*Nocellara del Belice*" and "*Cerasuola*" for six consecutive years is described in this paper. Parameters related to olive oil purity and shelf-life together with the composition (%) of sterols and fatty acids of the single oils are shown. Data were analyzed by the univariate non-parametric Mann-Whitney test and the multivariate procedure of Factor Analysis.

KEY-WORDS: Characterization - Olive oil - Quality - Variety.

1. INTRODUCTION

The olive oil and table olive industries play an important role in the agricultural and processing sectors of the major olive producing countries. Most olive oil is consumed within the Mediterranean countries and only 18% is sold outside the EU. Olive oil, in addition to culinary use, has recently become more valued for its health benefits and, also for this reason, its consumption has increased in several non-Mediterranean countries (e.g. USA, Australia and Japan).

Italy is one of the largest olive oil producers, with approximately 425.000 tons of olive oil per year. Six olive oil varieties have been studied and characterized - *Minuta* (Salvo et al., 1998), the *Santagatese* (Dugo G.mo et al., 1999a), the *Nocellara del Belice* (Dugo G.mo et al., 2000), the *Ogliarola Messinese* (Lo Curto et al., 2001), the *Moresca* and the *Tonda Iblea* (Lo Curto et al., 2002) – as part of an extensive study of Southern Italian olive oils, with a particular reference to Sicily.. The research comprized studies on the varieties' shelf-life and tocopherol content (Dugo G.mo et al., 1999b; Lo Curto, 2001a) carried out by means of statistical procedures (Saitta et al., 2000; Lo Curto, 2001b).

The present study focused on the characterization of the variety *Cerasuola* and its comparison with *Nocellara del Belice*, the former being harvested in three neighboring olive growing zones while the latter was collected from particular geographical origin. The chemical and physical-chemical parameters of the varieties analyzed for six consecutive crops did not show great variations.

2. EXPERIMENTAL

2.1. Samples

214 olive oil samples were characterized by various physical-chemical parameters. 82 samples belong to *Cerasuola* virgin olive oils - collected from Trapani ("D.O.P.- Valli Trapanesi") (EC Regulations 2325/97), Palermo ("D.O.P.- Val di Mazara") (EC Regulations 138/01), and Agrigento territories - while 132 samples belong to *Nocellara del Belice* virgin olive oils, produced in the Trapani province only ("Valle del Belice") (Dugo G.mo (2001). Olive oils were collected for six consecutive crops (1995/96-2000/01), stored in dark glass bottles with hermetic sealing and stored at +4°C. All samples were submitted for statistical analyses.

2.2. Chemical analyses

In agreement with Analytical Official Methods (EC Regulations 2568/91), chemicals and chemical-physicals analyses, were determined, for all samples.

In addition, Rancimat test induction time and total phenols content (gallic acid mg/Kg) were evaluated by a colorimetric method (Dugo G.mo et al., 1999b). Samples of each olive oil variety, produced in 1999/00, were stored in the dark at room temperature and examined again after one year to evaluate changes in chemical and chemical - physical parameters. UV spectra for K_{232} and K_{270} determinations were determined using a Shimadzu UV-2401 PC UV-visible spectrophotometer.

The determination of total sterol components was carried out in a Shimadzu GC 17A instrument equipped with a flame ionization detector and a split-splitless injector in the following experimental conditions: column temperature was isotherm, 250°C; column SPB 5, 25 m x 0.32 mm i.d., 0.25 μm film thickness; injector and detector temperature, 280°C; carrier gas, hydrogen at a linear velocity of 50 cm/sec.

Fatty acids were determined as methyl esters, in a Shimadzu GC 17A instrument equipped with a flame ionization detector and a split-splitless injector in the following experimental conditions: fused silica column Supelco Omega wax 320, 30 m x 32 mm i.d., 0.25 μm film thickness; injector temperature 220°C; detector temperature 260°C; oven temperature programmed from 150°C (8 min) to 180°C at 2°C/min, then to 210°C at 5 °C/min (30 min); carrier gas, hydrogen at a linear velocity of 50 cm/sec.

Rancimat test induction time was determined by a Metrohm 679 apparatus, set at 120°C (± 0.2°C) and with 20 L/h air per inlet, on a 2.5 g quantity of oil (Dugo G.mo et al.,1999b).

2.3. Statistical data analyses

The analytical data were processed by statistical procedures: Factor Analysis and Mann-Whitney test (Snedecor, G.W. 1989; Jobson, J.D., 1992). Factor Analysis involves finding a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with minimum loss of information.

The Mann-Whitney test is a nonparametric test that does not require assumptions about the shape of underlying distributions. It tests the hypothesis that two independent samples come from populations having the same distribution.

The Wilcoxon statistic, W, is calculated by ranking the pooled observations of the two samples and obtaining the sum of the ranks of the population with the smaller sample size. The Mann-Whitney statistic, U, which is equivalent to the Wilcoxon statistic, is obtained by counting the observations from the group with the smaller sample size that precede an observation from the larger group. If the significance level is more than 0.05, then the hypothesis that the variables have the same distribution for the two groups is not to be ruled out.

3. RESULTS AND DISCUSSION

3.1. Physical and chemical parameters

The number of *Cerasuola* and *Nocellara del Belice* samples and the origin of the oils, are reported in Table I. Table II shows maximum, mean, minimum values and standard deviations of the varieties' physical and chemical characteristics: almost all the values are included in limits for extra virgin olive oils (EC Regulations, 2568/91) except, for two samples of *Nocellara del Belice* in years 95/96 and 97/98. For all the samples of *Cerasuola* variety, Trapani zone, (Table III) a total phenols mean value of 260 ± 97 mg/Kg and a mean induction time of 10.5 ± 3.0 h/120°C, were found. This group seems to produce oils with better characteristics against Agrigento and Palermo oils.

3.2. Shelf- life

Table IV reports the mean values of free acidity, peroxide number, UV index and total phenols for samples of only one year 1999/00, compared to the ones obtained from the same oils after one year of shelf-life . It has been observed that, for *Cerasuola* and *Nocellara del Belice* oils, free acidity, peroxide number and UV values tend to increase while total phenol content has a tendency to decrease, maintaining the characteristics of virgin olive oils.

3.3. Defect degree

In order to single out a parameter suitable to describe a "virgin olive oil quality state", an empirical formula was calculated by including free acidity, peroxide number, K_{232} and K_{270} values, phenols and Rancimat test induction time variables. To convert the first four factors, minimum and maximum current legal parameters were used as reference limits (EC Regulation, n. 2568/92); after normalization, they were applied to a 1-10 scale, that is inversely proportional to their values (for example, free acidity value of 0.1 is equivalent to 10 and a value of 3.3 fits to 1). For phenols and induction time, minimum and maximum values, extrapolated from a great number of real samples studied over several years, were used (a 400-40 mg/kg range for phenols and a 16.00-3.00 h/120°C range for Rancimat test induction time). These values are simply a quality

Table I
Samples numbering, cultivar and origin of the olive oils harvest in six years

Cultivar	Cerasuola		Nocellara del Belice	
Year	**Samples**	**Origin**	**Samples**	**Origin**
1995/96	7	Sciacca (AG), Paceco (TP), Buseto Palizzolo (TP), Monreale (PA), San Vito Lo Capo (TP).	19	Castelvetrano (TP), Partanna (TP)
1996/97	7	Sciacca (AG), Paceco (TP), Buseto Palizzolo (TP), Monreale (PA), San Vito Lo Capo (TP).	20	Castelvetrano (TP), Partanna (TP), Campobello di Mazara (TP)
1997/98	9	Sciacca (AG), Paceco (TP), Buseto Palizzolo (TP), Monreale (PA), San Vito Lo Capo (TP).	45	Castelvetrano (TP), Partanna (TP), Campobello di Mazara (TP)
1998/99	11	Sciacca (AG), Paceco (TP), Buseto Palizzolo (TP), Monreale (PA), San Vito Lo Capo (TP).	18	Castelvetrano (TP)
1999/00	36	Salemi (TP), Sciacca (AG), Paceco (TP), Partinico (PA).	16	Castelvetrano (TP)
2000/01	12	Paceco (TP).	14	Castelvetrano (TP)
Total	82		132	

Table II
***Cerasuola* and *Nocellara del Belice* variety physical and chemical parameters mean values for each year**

	Free acidity % oleic acid		Peroxide n. $meqO_2/Kg$		Phenols mg/Kg		Rancimat h/120°C		UV indices K_{232}		K_{270}		ΔK	
1995/96	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	2.04	3.10	11.0	13.2	144	538	15.1	13.4	1.70	2.77	0.15	0.23	0.000	0.009
Mean	0.64	0.63	7.6	9.8	107	281	9.5	8.6	1.57	1.85	0.12	0.17	0.000	0.002
Min	0.15	0.10	4.0	6.3	88	153	3.1	2.2	1.43	1.58	0.10	0.13	0.000	-0.001
St. Dev.	0.68	0.81	2.5	1.9	18	92	3.6	3.0	0.08	0.26	0.02	0.03	0.000	0.003
1996/97	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	0.60	1.20	8.0	11.0	131	219	13.3	12.7	2.09	2.49	0.18	0.19	0.000	0.010
Mean	0.40	0.63	4.7	5.8	111	138	9.7	8.1	1.86	1.96	0.13	0.13	0.000	0.001
Min	0.20	0.20	2.0	3.0	90	55	5.7	3.6	1.62	1.61	0.10	0.10	0.000	-0.002
St. Dev.	0.14	0.31	2.3	2.2	14	35	2.6	3.0	0.16	0.21	0.03	0.02	0.000	0.003
1997/98	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	1.50	2.50	13.0	11.0	189	437	11.3	12.5	1.62	1.96	0.14	0.32	0.005	0.060
Mean	0.58	0.53	6.0	4.7	136	182	7.6	7.3	1.37	1.58	0.12	0.13	0.001	0.000
Min	0.10	0.10	2.0	1.0	78	36	3.7	2.4	1.16	1.23	0.10	0.04	-0.005	-0.090
St. Dev.	0.53	0.49	3.7	2.1	40	91	2.6	2.6	0.15	0.19	0.01	0.06	0.004	0.020
1998/99	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	0.61	0.40	9.5	14.0	344	310	12.2	16.1	1.82	1.72	0.16	0.13	0.000	0.005
Mean	0.32	0.19	6.6	7.1	209	174	8.1	8.8	1.60	1.35	0.13	0.09	-0.004	-0.002
Min	0.11	0.10	4.2	2.0	104	119	4.6	5.2	1.38	1.00	0.09	0.04	-0.010	-0.015
St. Dev.	0.18	0.09	1.9	2.7	67	59	2.2	3.3	0.17	0.18	0.02	0.02	0.004	0.005
1999/00	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	0.54	0.60	19.8	8.1	399	306	16.5	14.8	2.22	1.82	0.26	0.12	0.000	0.000
Mean	0.22	0.23	4.9	5.0	237	214	10.5	10.7	1.55	1.52	0.13	0.09	-0.006	-0.005
Min	0.14	0.14	2.1	2.6	98	87	6.0	7.2	1.36	1.17	0.08	0.06	-0.010	-0.008
St. Dev.	0.09	0.14	3.3	1.6	85	63	3.2	1.9	0.16	0.15	0.04	0.02	0.002	0.003
2000/01	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	1.50	0.28	12.6	6.5	497	396	15.0	16.1	1.79	1.95	0.18	0.18	0.003	-0.004
Mean	0.29	0.18	7.6	3.9	353	275	11.5	11.3	1.61	1.60	0.12	0.10	-0.003	-0.006
Min	0.12	0.13	3.2	2.1	233	170	8.7	6.5	1.46	1.39	0.08	0.04	-0.005	-0.009
St. Dev.	0.38	0.04	3.4	1.5	69	68	2.0	3.0	0.11	0.17	0.03	0.04	0.002	0.002

C = Cerasuola; N = Nocellara del Belice

index and not required by law. They referred to a 1-5 scale that is directly proportional to parameter values, since it is known that they progressively decrease over time, thus worsening the quality of the oil.

The formula is described as follows:

$$\text{Defect degree'}=60-\left(10-\frac{A}{0.355}\right)-\left(10-\frac{P}{2.22}\right)-\left(10-\frac{K_{232}}{0.41}\right)-\left(10-\frac{K_{270}}{0.027}\right)-\frac{TP}{80.44}-\frac{IT}{2.6}$$

Table III
Cerasuola variety physical and chemical parameters mean values for each territory

	Free acidity % oleic acid	Peroxide n. $meqO_2$/Kg	Phenols mg/Kg	Rancimat h/120°C	UV indices K_{232}	K_{270}	ΔK
Agrigento							
Max	0.50	19.8	344	11.4	1.87	0.16	0.000
Mean	0.24	6.9	154	10.2	1.56	0.14	0.000
Min	0.10	2.0	98	8.6	1.43	0.12	-0.002
St. Dev.	0.15	6.6	95	1.3	0.17	0.01	0.001
Palermo							
Max	1.50	13.9	400	14.0	2.09	0.18	0.005
Mean	0.47	6.4	158	8.5	1.54	0.11	-0.003
Min	0.14	2.0	78	3.7	1.30	0.08	-0.010
St. Dev.	0.35	3.1	70	2.8	0.18	0.03	0.004
Trapani							
Max	2.04	12.6	497	16.5	2.22	0.26	0.005
Mean	0.27	5.4	260	10.5	1.59	0.13	-0.004
Min	0.12	2.0	88	3.1	1.16	0.08	-0.010
St. Dev.	0.33	2.6	97	3.0	0.18	0.04	0.003

Table IV
Cerasuola and _Nocellara del Belice_ variety (1999/00) physical and chemical parameters mean values at production stage and after one year

	Free acidity % oleic acid		Peroxide n. meq O_2/Kg		UV indices K_{232}		K_{270}		ΔK		Total phenols mg/Kg	
Cerasuola	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
Max	0.54	0.96	13.9	14.0	2.22	2.25	0.20	0.20	0.000	0.002	400	380
Mean	0.22	0.27	4.5	6.0	1.55	1.63	0.12	0.13	-0.006	-0.002	238	222
Min	0.14	0.14	2.1	2.5	1.36	1.38	0.08	0.08	-0.010	-0.005	102	100
St. Dev.	0.09	0.16	2.2	2.6	0.16	0.19	0.03	0.03	0.002	0.002	83	78
Nocellara del Belice	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
Max	0.26	0.62	8.1	8.6	1.66	1.92	0.11	0.16	-0.004	0.000	306	149
Mean	0.19	0.33	5.5	6.3	1.49	1.68	0.08	0.11	-0.006	-0.002	217	115
Min	0.14	0.20	3.5	4.9	1.17	1.43	0.06	0.08	-0.008	-0.006	112	76
St. Dev.	0.03	0.13	1.5	1.4	0.14	0.15	0.02	0.03	0.001	0.002	61	18

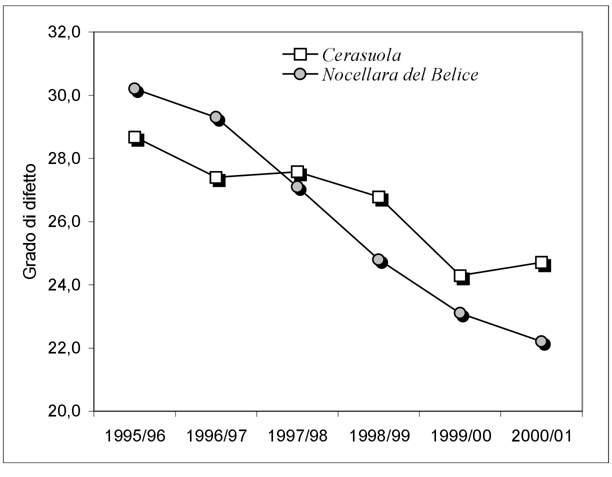

Figure 1
Cerasuola and *Nocellara del Belice* varieties 'defect degree' trend in six years (1995/96 – 2000/01).

where A is free acidity, P is peroxide number, K_{232} and K_{270} are UV índices, TP are total phenols and IT is induction time (Rancimat test). From a data analysis, a value of 55 was determined for oils with the hypothetical worst physical and chemical parameters and a value of 16 was assigned for oils with the hypothetical optimal physical and chemical parameters; obviously, the lower the 'defect degree' is, the better the oil is considered . This new parameter was calculated on samples mean data over six years. The quality of the oils seems to have been enhanced during the years for both cultivars (Figure 1). The value of *Nocellara del Belice* (26.6) was higher than *Cerasuola* (24.6) for the oils collected in Trapani (26.6) although the latter showed higher values in oils from other geographical origins (Agrigento: 26.8; Palermo: 26.9).

Table V

***Cerasuola* and *Nocellara del Belice* sterols mean values for each year**

	Campesterol %		Campestanol %		Stigmasterol %		Clerosterol %		β-sitosterol %		Sitostanol %		Δ^5-avenasterol %		$\Delta^{5,24}$-stigmastadienol%		Δ^7-stigasterol%		Δ^7-avenasterol %		Total β-sitosterol%		Campesterol / Stigmasterol		Total sterols mg/Kg		Erythrodiol + uvaol[a]%	
1995/96	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.7	4.0	0.5	0.7	1.5	2.1	1.1	1.2	86.1	87.5	0.8	0.9	16.8	7.9	0.7	1.0	0.4	0.4	0.5	0.5	94.5	96.1	4.5	4.9	1403	1250	3.5	3.4
Mean	3.4	3.5	0.4	0.5	1.1	1.4	0.8	0.8	82.6	86.1	0.6	0.4	9.4	5.9	0.5	0.3	0.3	0.3	0.4	0.2	94.3	93.5	3.2	2.7	1208	1056	1.8	1.9
Min	2.7	2.1	0.3	0.1	0.8	0.8	0.5	0.2	75.5	85.0	0.5	0.2	5.9	5.1	0.4	0.0	0.2	0.0	0.3	0.1	94.0	92.9	1.8	1.4	1048	980	0.6	1.1
St. Dev.	0.3	0.5	0.1	0.2	0.3	0.4	0.2	0.3	3.4	0.7	0.1	0.2	3.6	0.8	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.7	0.9	1.0	109	75	1.0	0.7
1996/97	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.6	3.7	0.6	0.6	1.1	2.9	1.1	1.3	85.9	86.5	1.1	1.0	10.7	10.8	0.9	0.9	0.5	0.5	0.7	0.7	94.7	94.5	6.8	4.6	1592	1556	3.1	3.9
Mean	3.2	3.1	0.4	0.5	0.9	1.6	0.8	1.1	83.2	84.9	0.9	0.3	8.7	6.8	0.6	0.4	0.4	0.3	0.5	0.3	94.1	93.5	4.1	2.2	1255	1027	1.6	2.9
Min	2.4	2.4	0.3	0.2	0.5	0.8	0.6	0.2	81.2	81.1	0.5	0.0	5.7	4.5	0.4	0.2	0.2	0.2	0.3	0.1	93.8	92.7	2.3	0.9	830	915	0.6	1.6
St. Dev.	0.4	0.4	0.1	0.1	0.2	0.4	0.2	0.2	1.8	1.3	0.2	0.3	2.1	1.2	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.5	1.5	0.7	288	152	0.8	0.8
1997/98	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.2	3.8	0.9	1.9	2.2	2.4	1.2	1.2	86.1	90.1	1.8	1.8	11.0	11.2	1.0	1.1	0.5	0.5	0.5	1.0	94.7	94.6	6.5	3.4	1572	1395	2.7	4.0
Mean	2.9	2.9	0.6	0.9	1.5	1.6	1.0	0.9	83.4	85.5	1.1	0.7	7.9	5.7	0.5	0.7	0.3	0.3	0.4	0.3	93.8	93.3	2.5	1.9	1127	1053	1.9	1.7
Min	2.4	1.6	0.4	0.1	0.5	0.9	0.8	0.2	80.6	80.9	0.5	0.1	6.2	1.8	0.2	0.1	0.1	0.1	0.1	0.1	93.0	92.6	1.3	1.0	961	930	1.1	0.2
St. Dev.	0.3	0.5	0.2	0.3	0.6	0.3	0.1	0.3	1.9	2.2	0.5	0.6	1.5	2.1	0.3	0.3	0.2	0.1	0.2	0.3	0.7	0.5	1.7	0.6	176	118	0.6	1.0
1998/99	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.9	3.9	0.6	1.4	2.2	1.7	1.2	1.4	85.3	89.5	0.8	0.8	8.5	8.1	1.0	0.5	0.6	0.5	1.1	0.7	94.4	96.3	4.8	4.4	1787	1253	0.6	2.8
Mean	3.4	3.3	0.5	0.9	1.3	1.2	1.1	1.0	83.8	86.6	0.5	0.4	7.4	5.2	0.6	0.4	0.3	0.2	0.6	0.2	93.5	93.4	3.0	2.9	1256	1043	0.3	1.3
Min	3.1	1.7	0.4	0.5	0.8	0.6	0.6	0.5	81.7	82.7	0.1	0.1	6.7	3.5	0.4	0.1	0.1	0.1	0.3	0.1	93.0	92.4	1.5	1.9	1007	919	0.1	0.2
St. Dev.	0.2	0.5	0.1	0.3	0.5	0.3	0.2	0.2	1.0	1.6	0.2	0.2	0.7	1.4	0.2	0.1	0.2	0.1	0.2	0.1	0.5	1.0	1.1	0.7	225	98	0.1	0.7
1999/00	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.9	3.8	0.6	1.4	1.5	1.9	1.2	1.1	86.3	88.1	1.9	1.3	12.6	7.8	1.0	0.9	0.5	0.4	1.1	1.0	95.1	93.9	7.1	3.4	1832	1140	2.8	4.2
Mean	3.3	3.5	0.5	0.9	0.9	1.4	0.8	0.8	84.1	85.5	1.0	0.7	7.5	5.5	0.6	0.5	0.3	0.3	0.6	0.4	94.0	93.0	4.2	2.6	1340	1050	1.3	2.0
Min	2.4	3.0	0.3	0.2	0.4	1.1	0.1	0.4	78.2	82.7	0.1	0.1	5.4	3.3	0.1	0.2	0.1	0.1	0.1	0.1	93.0	92.3	2.0	1.7	1015	961	0.6	0.5
St. Dev.	0.5	0.3	0.1	0.3	0.3	0.2	0.2	0.2	2.0	1.5	0.4	0.5	1.8	1.3	0.2	0.2	0.1	0.1	0.2	0.2	0.6	0.4	1.4	0.5	218	46	0.5	1.1
2000/01	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max	3.9	4.0	0.7	1.1	1.8	1.2	1.2	1.2	85.4	87.7	1.4	0.8	11.7	7.1	0.9	0.9	0.5	0.5	1.1	0.7	95.0	94.0	7.0	4.7	1819	1273	3.3	3.3
Mean	3.3	3.7	0.5	0.8	0.8	1.0	1.1	1.0	82.8	85.8	0.7	0.3	8.6	5.7	0.7	0.6	0.4	0.3	0.6	0.4	93.9	93.4	4.6	3.8	1372	1040	1.6	1.5
Min	2.1	3.0	0.3	0.4	0.6	0.8	1.0	0.9	80.1	83.9	0.3	0.1	6.1	3.7	0.3	0.3	0.2	0.1	0.3	0.1	93.2	92.7	1.5	3.1	1007	917	0.7	0.7
St. Dev.	0.5	0.3	0.1	0.2	0.4	0.1	0.1	0.1	2.1	1.0	0.4	0.2	1.8	1.0	0.2	0.2	0.1	0.1	0.2	0.2	0.5	0.4	1.5	0.5	282	115	0.8	0.7

[a]percentages referred to sterols fraction

3.4. Sterols composition

Table V shows the mean values of sterols and the total of erythrodiol and uvaol for both varieties. The data, refering to six years, show several differences between both cultivars. The greatest percentage of β-sitosterol found in *Cerasuola* samples was 84.1 ± 2.0 for year 1999/00, and the lowest was 82.6 ± 3.4, for 1995/96 production *vice versa*, for the *Nocellara del Belice* variety the greatest percentage found was 86.6 ± 1.6 (year 1998/99) and the lowest was 84.9 ± 1.3 (year 1996/97). The oils obtained from the *Nocellara del Belice* variety show a total β-sitosterol content equal to or slightly better than the law limit for olive oils, that must be =93.0% (EC Regulations 2568/91), but it could be a peculiarity of the oil, because it's recurring in almost all of *Nocellara* samples (Dugo G.mo et al., 2000). The values of *Cerasuola* samples grown in three neighboring territories are reported and there are no significant differences (Table VI).

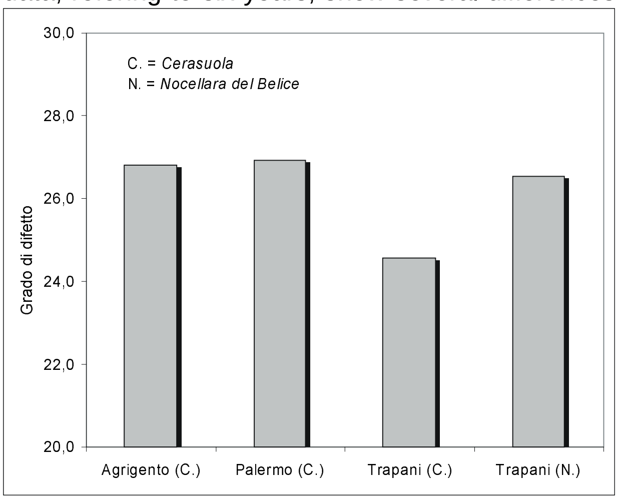

Figure 2

"Defect degree" on: *Cerasuola* (harvested in three neighbouring territories) and *Nocellara del Belice* variety.

3.5. Fatty acids composition

The fatty acid fraction of analyzed samples over six years, see Table VII, are reported. The *Cerasuola* variety shows oleic acid in a range from 74.3 ± 1.1 (2000/01) to 77.5 ± 2.2 (99/00), unlike the *Nocellara* that was spanned from 69.9 ± 1.5 (95/96) to 75.5 ± 1.1 for the 2000/01 production. Palmitic acid percentages

Table VI
***Cerasuola* variety sterols mean values for each territory**

		Campesterol %	Campestanol %	Stigmasterol %	Clerosterol %	β-Sitosterol %	Sitostanol %	Δ^5-Avenasterol %	$\Delta^{5.24}$-Stigmastadienol %	Δ^7-Stigmastenol %	Δ^7-Avenasterol %	total β-Sitosterol %	Campesterol/ Stigmasterol	Total sterols mg/Kg	Erythrodyol + Uvaol[a] %
Agrigento															
	Max	3.6	0.5	1.8	1.2	86.3	1.2	16.8	1.0	0.5	0.9	94.7	6.5	1592	3.5
	Mean	3.1	0.4	1.1	0.9	82.0	0.8	9.9	0.7	0.3	0.4	94.3	3.6	1182	1.8
	Min	2.4	0.4	0.5	0.7	75.5	0.5	6.6	0.2	0.1	0.1	93.0	1.8	961	0.1
	St. Dev.	0.4	0.1	0.5	0.2	3.9	0.2	3.8	0.3	0.1	0.3	0.7	2.2	228	1.4
Palermo															
	Max	3.9	0.8	2.2	1.2	86.3	1.8	10.7	0.9	0.6	1.1	94.7	7.1	1787	3.1
	Mean	3.3	0.5	1.1	0.9	83.9	0.8	7.6	0.5	0.3	0.5	93.8	3.7	1254	1.1
	Min	2.4	0.3	0.5	0.5	80.9	0.1	5.9	0.1	0.1	0.1	93.0	1.3	830	0.2
	St. Dev.	0.4	0.1	0.5	0.2	1.7	0.4	1.6	0.2	0.1	0.2	0.5	1.7	230	0.7
Trapani															
	Max	3.9	0.9	1.9	1.2	86.1	1.9	12.6	1.0	0.5	1.1	95.1	7.0	1832	3.3
	Mean	3.2	0.5	0.9	0.9	83.6	0.9	7.9	0.6	0.3	0.6	93.9	3.9	1331	1.3
	Min	2.1	0.3	0.4	0.1	78.2	0.3	5.4	0.2	0.1	0.3	93.0	1.4	1007	0.2
	St. Dev.	0.5	0.1	0.4	0.2	1.9	0.4	1.7	0.2	0.1	0.2	0.6	1.3	231	0.7

[a]percentages referred to sterols fraction

are 9.9 ± 1.1 for the first variety and 13.5 ± 2.1 for the second one; linoleic acid percentages are 9.3 ± 1.9 for *Cerasuola* and 8.3 ± 1.3 for *Nocellara del Belice.*

By observing the *Cerasuola* oils grouped by provinces of origin (Table VIII), Agrigento samples have the higher percentages of palmitic and palmitoleic acid, of saturated acids and the greater palmitic/linoleic ratio against Palermo and Trapani oils.

3.6. Statistical data results

A principal components analysis was carried out on the parameters of the olive oil varieties. Eight factors were needed to explain 71% of the total variance. Thus, factor 1 which accounts for % of the explained variance is mainly based on the variables palmitic and palmitoleic acids, induction time and total phenols. The other factors present lower levels so they are not considered in further steps. Estimating factor scores from the data values, they have been plotted considering only the first two factors. The scatter plot (Figure 3) shows that the two varieties *Cerasuola* and *Nocellara del Belice* are well separated. On the one hand, the positive values for factor 1 indicate that the samples belonging to *Nocellara* have a high concentration of palmitic and palmitoleic acids, a high value of induction time and a lower concentration of phenols; the situation is opposite for the *Cerasuola* variety. On the other hand, factor 2 shows values distributed around 0, so it does not underline any particular characteristic of the two cultivars.

Considering Mann-Whitney test, the values of U and W have been calculated for every one of the 25 variables between the two groups of varieties including 214 samples. The *Cerasuola* variety includes 82 samples; the *Nocellara del Belice* includes 132 samples. U and W statistics are used to calculate the significance levels for each variable. The results show that only for the variables clerosterol, eptadecanoic acid, campesterol,

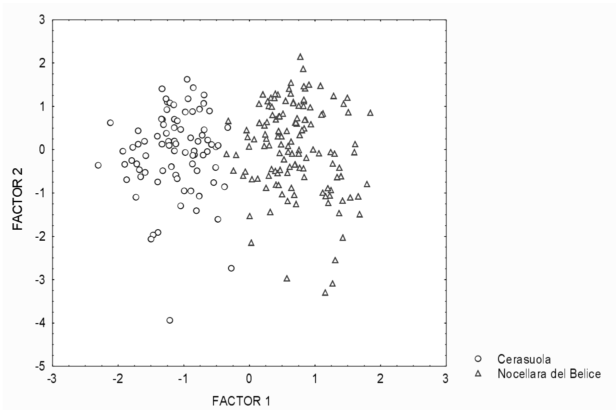

Figure 3
Results of applying principal component analysis to Cerasuola and *Nocellara del Belice* samples.

Table VII

***Cerasuola* and *Nocellara del Belice* fatty acids mean values for each year**

	C_{16}		$C_{16:1}$		C_{17}		$C_{17:1}$		C_{18}		$C_{18:1}$		$C_{18:2}$		$C_{18:3}$		C_{20}		$C_{20:1}$		Saturated		Mono unsaturated		Poly unsaturated		unsat/sat		$C_{16}/C_{18:2}$		$C_{18:1}/C_{18:2}$	
	%		%		%		%		%		%		%		%		%		%		%		%		%							
1995/96	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	12.1	19.0	1.10	1.61	0.20	0.20	0.30	0.30	3.5	3.0	78. 0	72.2	9.8	9.3	0.78	0.78	0.46	0.48	0.47	0.39	15.8	22.2	79.5	73.6	10.4	9.9	7.8	4.4	1.38	0.28	9.4	11.6
Mean	10.4	17.1	0.46	1.25	0.14	0.09	0.13	0.11	2.9	2.7	75.7	69.9	8.8	7.5	0.63	0.66	0.37	0.25	0.32	0.20	14.0	20.3	76.6	71.5	9.4	8.2	6.2	3.9	1.18	0.25	8.6	9.4
Min.	9.4	15.1	0.21	0.94	0.07	0.06	0.05	0.07	1.6	2.2	74.2	67.3	8.1	6.2	0.56	0.61	0.13	0.18	0.10	0.08	11.4	18.5	74.8	69.3	8.9	6.8	5.3	3.5	1.05	0.21	7.6	7.3
St. Dev.	0.9	1.2	0.30	0.19	0.05	0.03	0.09	0.05	0.6	0.2	1.3	1.5	0.6	0.7	0.09	0.04	0.11	0.06	0.13	0.07	1.3	1.1	1.5	1.4	0.6	0.7	0.8	0.3	0.11	0.02	0.7	1.1
1996/97	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	13.4	14.0	1.40	1.42	0.13	0.07	0.23	0.17	3.9	3.4	77.7	79.4	11.9	11.4	0.70	0.86	0.45	0.61	0.46	0.49	16.4	17.5	78.4	80.7	12.6	12.1	7.0	7.5	1.29	0.19	10.8	11.5
Mean	10.4	11.9	0.53	1.05	0.06	0.04	0.09	0.10	2.8	2.6	74.6	74.3	9.9	8.2	0.64	0.78	0.40	0.48	0.40	0.42	13.8	15.2	75.6	75.9	10.6	9.0	6.3	5.7	1.07	0.16	7.8	9.3
Min.	9.2	9.2	0.31	0.53	0.04	0.03	0.05	0.07	2.3	1.9	70.0	70.9	7.2	6.7	0.58	0.69	0.35	0.25	0.35	0.34	12.6	11.7	72.1	72.8	7.8	7.5	5.1	4.7	0.88	0.12	6.1	6.5
St. Dev.	1.5	1.2	0.39	0.23	0.03	0.01	0.06	0.03	0.5	0.4	2.9	2.2	1.8	1.3	0.04	0.05	0.04	0.10	0.04	0.04	1.3	1.4	2.6	2.1	1.8	1.3	0.6	0.7	0.17	0.02	1.8	1.6
1997/98	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	12.9	16.5	0.58	2.01	0.09	0.16	0.24	0.33	2.9	3.5	76.7	82.3	10.4	12.9	0.70	0.98	0.45	0.60	0.38	0.49	16.1	19.5	77.5	83.3	11.1	13.8	6.1	7.6	1.47	0.24	9.9	18.3
Mean	11.7	13.6	0.45	1.07	0.05	0.05	0.10	0.10	2.7	2.9	74.7	71.8	9.0	8.9	0.61	0.77	0.34	0.42	0.32	0.25	14.8	17.1	75.6	73.2	9.6	9.7	5.8	4.9	1.31	0.19	8.4	8.3
Min.	10.9	8.1	0.34	0.32	0.03	0.02	0.05	0.06	2.3	2.0	73.2	65.6	7.8	4.5	0.49	0.10	0.23	0.20	0.25	0.16	14.2	11.7	74.1	67.6	8.3	5.0	5.2	4.1	1.08	0.10	7.1	5.1
St. Dev.	0.7	1.6	0.09	0.27	0.02	0.02	0.06	0.05	0.2	0.3	1.1	2.5	0.8	1.4	0.07	0.13	0.08	0.09	0.05	0.07	0.7	1.6	1.1	2.3	0.9	1.4	0.3	0.6	0.14	0.03	0.9	1.9
1998/99	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	11.6	17.5	0.96	1.98	0.09	0.04	0.13	0.08	2.9	3.4	79.1	76.0	11.0	10.5	0.71	0.83	0.44	0.45	0.39	0.24	14.7	20.4	79.8	77.1	11.7	11.2	7.9	6.7	1.46	0.26	11.7	9.7
Mean	9.8	12.6	0.45	0.92	0.06	0.03	0.08	0.06	2.6	2.8	77.0	73.2	8.7	9.0	0.58	0.72	0.39	0.37	0.32	0.20	13.0	16.0	77.8	74.4	9.3	9.7	6.8	5.3	1.14	0.17	9.1	8.3
Min.	8.3	10.2	0.24	0.64	0.04	0.02	0.05	0.03	2.2	2.0	73.5	67.0	6.7	7.8	0.46	0.57	0.35	0.26	0.21	0.15	11.2	13.0	74.4	69.2	7.3	8.5	5.8	3.9	0.90	0.13	6.7	6.7
St. Dev.	0.9	1.8	0.21	0.28	0.02	0.01	0.03	0.01	0.2	0.4	2.0	2.2	1.3	0.8	0.07	0.06	0.03	0.06	0.05	0.02	1.1	1.7	2.0	2.0	1.3	0.8	0.7	0.6	0.17	0.03	1.6	0.9
1999/00	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	11.5	15.6	0.36	1.53	0.20	0.07	0.42	0.10	3.2	3.5	80.4	75.5	13.4	10.0	0.55	0.63	0.56	0.53	0.27	0.25	14.5	19.5	80.8	76.7	14.0	10.3	8.1	5.5	1.62	0.21	13.4	11.6
Mean	9.7	13.8	0.28	0.98	0.06	0.05	0.09	0.08	2.6	2.9	77.5	73.6	8.7	7.6	0.42	0.29	0.44	0.47	0.09	0.18	12.9	17.3	78.0	74.9	9.1	7.8	6.8	4.8	1.15	0.19	9.3	9.9
Min.	7.6	11.8	0.21	0.11	0.02	0.02	0.04	0.03	2.2	1.1	72.6	70.4	6.0	6.2	0.25	0.18	0.26	0.36	0.01	0.11	11.0	15.5	73.1	71.8	6.3	6.4	5.9	4.1	0.69	0.16	5.4	7.1
St. Dev.	0.9	1.2	0.04	0.32	0.04	0.01	0.09	0.02	0.3	0.7	2.2	1.5	1.8	1.1	0.06	0.10	0.06	0.04	0.09	0.05	0.8	1.3	2.1	1.4	1.8	1.1	0.5	0.4	0.23	0.02	2.0	1.3
2000/01	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*	*C*	*N*
Max.	9.5	13.9	0.42	0.92	0.05	0.08	0.10	0.10	3.0	2.9	76.0	77.1	13.1	8.8	0.74	0.91	0.53	0.43	0.44	0.23	13.0	16.9	76.8	77.9	13.8	9.6	7.8	6.4	0.94	0.19	7.6	11.4
Mean	8.9	11.9	0.34	0.77	0.04	0.04	0.06	0.07	2.8	2.6	74.3	75.5	11.9	7.6	0.64	0.87	0.45	0.39	0.39	0.15	12.4	15.1	75.1	76.5	12.5	8.5	7.1	5.7	0.76	0.16	6.3	10.0
Min.	8.3	10.5	0.26	0.50	0.03	0.02	0.03	0.06	2.5	2.3	72.6	73.8	9.9	6.7	0.54	0.82	0.37	0.36	0.36	0.01	11.4	13.6	73.5	75.0	10.6	7.6	6.7	4.9	0.64	0.14	5.6	8.4
St. Dev.	0.4	1.0	0.05	0.10	0.01	0.01	0.02	0.01	0.2	0.1	1.1	1.1	1.2	0.6	0.05	0.03	0.04	0.02	0.03	0.05	0.5	1.0	1.0	1.1	1.2	0.6	0.3	0.4	0.11	0.02	0.8	0.8

C = Cerasuola; N = Nocellara del Belice

Table VIII

***Cerasuola* variety fatty acids mean values for each territory**

		C_{16}	$C_{16:1}$	C_{17}	$C_{17:1}$	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	C_{20}	$C_{20:1}$	Saturated	Mono unsaturated	Poly unsaturated	unsat/sat	$C_{16}/C_{18:2}$	$C_{18:1}/C_{18:2}$
		%	%	%	%	%	%	%	%	%	%	%	%	%			
Agrigento	Max.	13.4	1.4	0.20	0.30	2.7	78.0	10.9	0.78	0.45	0.46	16.4	79.5	11.5	7.8	1.47	9.5
	Mean	11.4	0.7	0.11	0.16	2.3	74.8	9.3	0.58	0.32	0.25	14.2	75.9	9.9	6.1	1.23	8.2
	Min.	9.4	0.2	0.04	0.06	1.6	70.0	8.0	0.45	0.13	0.03	11.4	72.1	8.5	5.1	0.99	6.4
	St. Dev	1.5	0.5	0.08	0.10	0.4	2.7	1.3	0.12	0.13	0.16	1.7	2.5	1.2	0.9	0.18	1.3
Palermo	Max.	12.3	1.0	0.10	0.14	3.9	79.1	13.4	0.71	0.56	0.41	15.4	79.8	14.0	7.9	1.46	11.7
	Mean	10.1	0.4	0.06	0.08	2.7	76.2	9.2	0.54	0.42	0.22	13.4	76.9	9.7	6.5	1.13	8.6
	Min.	8.3	0.2	0.04	0.05	2.2	72.6	6.7	0.39	0.35	0.01	11.2	73.1	7.3	5.5	0.69	5.4
	St. Dev	0.9	0.2	0.02	0.03	0.4	1.9	1.7	0.10	0.05	0.16	1.0	1.9	1.7	0.6	0.20	1.6
Trapani	Max.	12.9	0.6	0.20	0.42	3.5	80.4	13.1	0.74	0.55	0.47	16.1	80.8	13.8	8.1	1.62	13.4
	Mean	9.7	0.3	0.06	0.09	2.7	76.5	9.4	0.52	0.43	0.24	13.0	77.1	9.9	6.8	1.08	8.6
	Min.	7.6	0.2	0.02	0.03	2.2	72.5	6.0	0.25	0.26	0.02	11.0	73.4	6.3	5.2	0.64	5.6
	St. Dev	1.1	0.1	0.04	0.08	0.3	2.5	2.0	0.13	0.06	0.15	1.1	2.3	2.1	0.6	0.27	2.1

arachilic acid, eicosenoic acid, peroxide number, K_{232} and K_{270} it cannot be rejected the hypothesis that they have the same distribution inside the two groups of varieties.

It was observed, for both varieties, that their shelf-life varies from 2 to 3 years. After one year from bottling, we can observe only very low increases of free acidity, peroxide number and spectra data, as well as small decreases of induction time and total phenols. With regards to acidic composition, the main differences were found in *Cerasuola* oleic and linoleic acids with amounts higher than *Nocellara del Belice* compounds and in *Cerasuola* palmitic acid lower than the *Nocellara* one. Polyunsaturated fatty acids did not show oxidative degradation, as a sign of oil freshness and a good working procedure.

With regards to the legal limits (EC Regulations 2568/91), 93% of *Cerasuola* (Trapani) samples analyzed, in six crop years, have been classified as extra virgin olive oil; 5% as virgin olive oil and 2% as current virgin olive oil. 90% of *Nocellara del Belice* samples can be classified as extra virgin olive oil, 7% as virgin olive oil and 3% as current virgin olive oil.

For each variety, the 1999/00 samples analyzed at production time and selected to test their shelf-life, one year from bottling, have maintained all their extra virgin olive oil class.

The analytical study of *Cerasuola* and *Nocellara del Belice* olive oils over six consecutive years, confirms that these varieties produce great quality oils.

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