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Advance technology in virgin olive oil production from traditional and de-stoned pastes: Influence of the introduction of a heat exchanger on oil quality

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Abstract

An experimental investigation was carried out to evaluate the quality of virgin olive oils obtained when a de-stoner were used for the olive paste preparation in comparison to the use of a traditional stone mill. In order to improve the slightly differences of oil yields due to the use of the de-stoner also a heat exchanger has been introduced in the processing line. The experimental data showed that resistance to the oxidation, total phenols and pleasant volatile compounds were higher in the de-stoned olive oils than in the oils obtained from the whole paste. Resistance to oxidation was assessed by Rancimat method and showed a positive correlation with the amount of total phenols.

Keywords: Virgin olive oil; De-stoner; Total phenols; Volatile compounds

1. Introduction

The quality of virgin olive oil is strictly correlated with the quality of fruits, with the harvesting systems and mostly with the techniques utilized to extract the oil, especially the machines for crushing the olives, for the kneading of the olive paste and separation of the oil phase (Ranalli, Cabras, Iannucci, & Contento, 2001; Ranalli, Costantini, De Mattia, & Ferrante, 2000). All operations required in the oil extraction process take aim at to obtaining the highest quality of oil from fruits. In such context the phase of preparation of the olive paste is one of the most important stage of the process where oil is mechanically extracted from the fruits. A large increase in demand for high-quality virgin olive oil during the past few years can be attributed not only to its potential health benefits, but also to its particular organoleptic properties. The aim of increasing the quality standards for virgin olive oil is continuously stimulating the search for new technologies. In this sense, a new technological procedure is being developed that includes stone removal before the olive oil extraction process (Amirante et al., 2001). Virgin olive oil contains a great number of volatile and non-volatile compounds mainly phenolic compounds responsible for its fragrant and peculiar flavour, (Caruso et al., 1999). These substances also contribute to the stability of the oil (Caruso et al.,

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1999; Di Giovacchino, Solinas, & Miccoli, 1994; Montedoro et al., 1993; Ranalli & Martinelli, 1995) and protect consumers against cancer and atherosclerosis by impeding the oxidative modification of LDL and its adherence to the arterial wall (Armstrong et al., 1997; Nicolaïev et al., 1998). The different kinds of crushers used to produce olive pastes (Angerosa & Di Giacinto, 1995; Angerosa & Solinas, 1990) and the essential malaxation operation (Lanzani, Bondioli, Cozzoli, Folegatti, & Fedeli, 1990; Montedoro & Garofolo, 1984; Montedoro, 1992; Solinas, Di Giovacchino, & Mascolo, 1978) modify phenolic compound contents and are also responsible for the changes of volatiles because of the activation of enzymes involved in the lipoxygenase pathway. Morales, Aparicio, and Rios (1994) observed that the a number of volatile compounds were generated during the crushing-malaxation steps of oil production. These volatile compounds are mainly responsible for the flavour of olive oil, which is of prime importance in the food industry because it plays a significant role in consumer choice. The determination of volatile compounds highlights that C_6 and C_5 compounds mainly form the volatile fraction. The concentration of each of them, responsible for the different nuances of the positive attributes (Angerosa, Mostallino, Basti, & Vito, 2000), is dependent on the level and the activity of enzymes involved in the lipoxygenase pathway. The enzymatic levels are genetically determined, whereas the technological operations affect their activities.

In this work, we tested an innovative continuous processing line made up a de-stoner (instead of the usual metal crusher) and a new generation three phase decanter (without adding water), witch was compared with a stone mill-decanter processing line.

The action of stone mill and the de-stoner in olive paste preparation was compared and their effects on the quality of the oil yielded were evaluated.

The separation of the kernel, without a violent crushing of the fruit, concurs the reduction of the mechanical actions and reduces the heating responsible of the degradation and oxidation phenomena. It turns out opportune to specify that the de-stoned pastes give slightly lower extraction yields (Amirante, Baccioni, Bellomo, & Di Renzo, 1987; Amirante et al., 2002); therefore, in order to correct this disadvantage it is indispensable to bring some best modifications to the system. The extension of the times of malaxation influence positively the yields but can damage the final quality of the product. In fact, during this step, considerable changes in the chemical composition in the oil are introduced because of the dispersion of phenols in the waste water and the increase of degradative and oxidative phenomena (Amirante et al., 2001). In order to improve the efficiency of this innovative continuous system, an hypothesis can be constituted from the introduction of a heat exchanger between the de-stoner and the mixer, so all the olive paste arrive instantaneously to the malaxation temperature (27 °C) reducing the times necessary to increase the yields. The aim of the present work is to verify the influence of the employment of the de-stoner on the oil quality, on the phenol content and the volatile compounds. The introduction of a heat exchanger between the de-stoner and the mixer has been moreover experienced in order to raise the extraction yields and to estimate the effects of this modification of the system on the quality of the oil. The result of this research should lead to meaningful technological advances in virgin olive oil production.

2. Material and methods

2.1. Sample preparation

Olive fruits (*Olea europaea* L.) of the Coratina variety were harvested in olive groves of the same area near Foggia (Apulia–Italy) during a series of crop seasons from 2000/2001 to 2002/2003. Olives were randomly picked at industrial optimum ripening stage, according to their skin colour. Harvesting was done by hand, using rakes. The olives were put into 30 kg boxes and immediately taken to an industrial oil mill located in the area of Foggia (Apulia–Italy) In each season five oil samples were extracted, using a stone mill triple-phase decanter line (*Alfa Laval Olive Oil*, San Buca Val di Pesa, Florence Italy), five with a de-stoner triple-phase decanter line (*Alfa Laval Olive Oil*, San Buca Val di Pesa, Florence Italy) and five with a de-stoner equipped with a heat exchanger triple-phase decanter line (*Alfa Laval Olive Oil*, San Buca Val di Pesa, Florence Italy). In each test olive paste was kneaded for 30 min at 27 °C. In order to prevent the escape of the volatile compounds in the atmosphere during the malaxation step, the mixer has been watertight sluice with steel covers leaving in the upper part an amount of air equal to 15% of the total volume in order to have enough oxygen necessary to the production of volatile compounds from polyunsaturated fatty acid through the ''lipoxygenase pathway''. The centrifugal decanter employed is a new generation three phase decanter Alfa Laval X32 model, therefore no water was added to olive paste prior to centrifuge. The decanter process parameters were fixed in the same way for all trials. The flux diagram of the processing procedures are shown in Fig. 1.

All samples were filtered with anhydrous Na_2SO_4 and stored at −20 °C in darkness using amber glass bottles without head space until analysis. A total of 45 Coratina virgin olive oils from three successive crop seasons were used for this study.

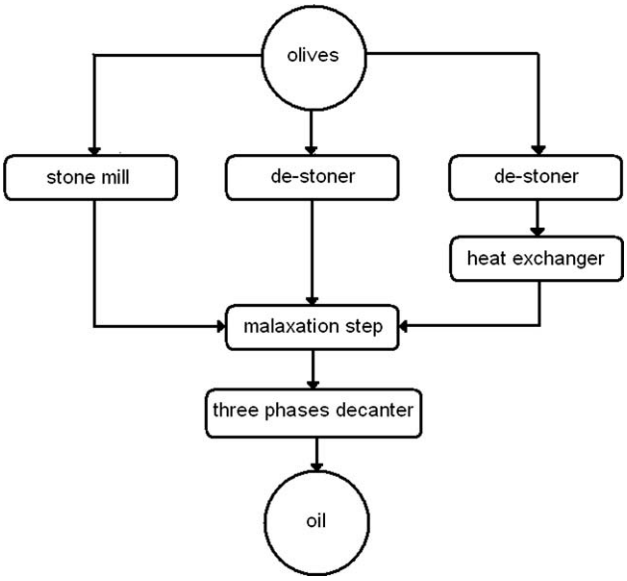

Fig. 1. Flux diagram of the processing procedures.

2.2. Reagent and standard

All solvents, for analysis, were purchased from J.T. Baker (Deventer, Netherlands). Hexanal and *cis*-2-penten-1-ol and nonan-1-ol were purchased from Aldrich (Steinheim, Germany), *cis*-3-hexen-1-ol and *trans*-2-hexen-1-ol from Fluka Co. (Buchs, Switzerland), *trans*-2-hexenal and 1 hexanol from E. Merck (Schuchardt, Germany).

2.3. Acidity value, peroxide index and ultra-violet light absorption

Acidity value, peroxide index and ultra-violet light absorption (K_{232}, K_{270}) were determined following the analytical methods described in the Regulation EEC/2568/91 of the Commission Regulation (1991).

2.4. Oxidative stability

Oxidation induction time was evaluated by the Rancimat method. Stability was expressed as the oxidation induction time (h), measured with the Rancimat apparatus (Metrohm AG, Herison, Switzerland) using an oil sample of 2.5 g, warmed to 120 °C and a purified air flow rate of 20 l/h. In the Rancimat method, the volatile degradation products were trapped in distilled water and determined conductometrically. The induction time was defined as the time necessary to reach the inflection point of the conductivity curve (Halbault, Barbé, Aroztegui, & De La Torre, 1997).

2.5. Total phenol content

Phenolic compounds were isolated from a solution of oil in hexane by triple-extraction with water–methanol (60:40 v/v). Total phenols, expressed as gallic acid equivalents (ppm), were determined with a UV visible spectrophotometer (Beckman) at 765 nm using the Folin-Ciocalteu reagent (Swain & Hillis, 1969).

2.6. Aromatic fraction

Pleasant volatile compounds were analyzed adding 2 ml of known strength 1-nonanoyl mixture (final concentration 80 mg/kg) to 3.5 g of olive oil. The analysis was carried out by a PURGE & TRAP system connected to a GC-MS. GC analytical conditions were: silica capillary column "VOCOL" 60 m × 0.32 mm, film 1.8 μm; planned column temperature: from 35 °C (10 min) to 103 °C (1 °C/min), than to 220 °C (15 °C/min), 220 °C for 20 min; injector temperature: 220 °C; detector temperature: 230 °C; gas carrier: helium, linear speed: 33.1 cm/s; acquisition in full scan from 40 to 500D.

Purge & Trap system bath temperature was 60 °C with an equilibrium time of 5 min. Stripping conditions: Helium temperature was 60 °C, stripping time was 20 min, active coal trap temperature was 35 °C. The volatile compounds transfer was protracted to 5 min heating the trap at 200 °C. Than the line was cleaned for 3 min.

2.7. Sensory analysis

Sensory analysis was carried out by an analytical panel of the APROL Lecce (Association of olive oil producers of Lecce) made up of 12 assessors according to European Official Methods of Analysis EEC/2568/91 and a sensory laboratory were used. All assessors had more than 8 years of experience in evaluating any olive oil types (extra-virgin, virgin, lampant, and refined). Oil samples were heated at 30 °C by a thermostat before sensory analyses and were presented fully randomized to the tasters. Dark-blue glasses were used as no colour evaluation was to be made. Each oil was graded on a scale from 1 to 9, where 1 is very poor quality. The modifications to European Official Methods of Analysis EEC/2568/91, ECC/796/02 and ECC/1989/03,were not applied because were not still in vigour in the first year of the experimentation. The modifications to European Official Methods of Analysis EEC/2568/91, ECC/796/02 and ECC/1989/03, were not still in vigour in the first year of the experimentation. The oil samples (no. 45) were stored frozen until the moment of the sensory and chemical analyses.

2.8. Statistical analysis

Statistical analysis was carried out using Microsoft Excel software. Significant differences between treatments were determined using one-way ANOVA followed by "Duncan's test" ($p < 0.05$).

3. Result and discussion

3.1. Olive oil extraction yields

A great number of different methods to improve oil yields have been experimented on integral paste and this confirm the importance of this problem (Ranalli, Gomes, Delcuratolo, Contento, & Lucera, 2003; Ranalli, Lucera, Contento, Simone, & Del Re, 2004; Ranalli, Malfatti, & Cabras, 2001; Ranalli, Malfatti, Pollastri, Contento, & Lucera, 2003; Ranalli, Pollastri, Contento, Lucera, & Del Re, 2003).

The employment of the de-stoner causes a lower yield equal to about 1.5 kg of oil for 100 kg of olives (Amirante et al., 1987). A percentage equal to about 30% of this difference is due to the oil fraction present in the kernel, the remaining percentage are due to the extraction process that in the course of the years has been optimized in function of the rheological characteristics of the whole olive paste.

The absence of stone fragments cause a change of the olive paste viscosity and a less efficient the effect of the malaxation. The malaxation have the aim to help the small droplets of the oil formed during the milling to merge in large drops that can be easily separated through mechanical system.

The introduction of the heat exchanger represents a system improvement finalized to increase the efficiency of malaxation of de-stoned paste. The heat exchanger, in fact, concurred to increase the slightly lower yields that were obtained only using the de-stoner. Fig. 2 shows the mean values of olive oil extraction yields obtained by three different paste preparation techniques during three crop seasons.

3.2. Acidity value, peroxide index

The oils examined were defined as belonging to the commercial class of extra virgin olive oil. The values obtained employing the official analytical methods are reported in Table 1. No substantial difference was noticed which was related to the olive paste preparation technique. All the values obtained in the experiments have been divided according to the crop season and the paste preparation technique used and are reported synthetically as mean values with their standard deviations.

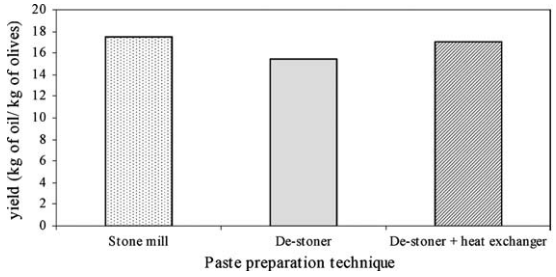

Fig. 2. Mean values of olive oil extraction yields obtained by three different paste preparation techniques during three crop seasons.

3.3. Oxidative stability and total phenol content

Since the occurrence of hydrophilic phenols in virgin olive oil is strictly related to the activities of various endogenous enzymes of olive fruit, their concentration in the oil is strongly affected by the extraction conditions. Crushing and malaxation are the most important critical points of the oil mechanical extraction process (Servili et al., 2004). Table 1 reports the results of analyses performed on oils extracted employing the three olive paste preparation techniques in three crop seasons. All the values obtained in the experiments have been divided according to the paste preparation technique used and are reported synthetically as mean values with their standard deviations. In these tests, when

Table 1
Standard quality parameters, induction time and polyphenols of olive oils obtained by three different paste preparation techniques during three harvesting years

	SM		DS		DH	
	m	SD	*m*	SD	*m*	SD
Olive paste preparation techniques						
2000/2001						
A	0.21 ns	0.02	0.20 ns	0.03	0.19 ns	0.03
PV	4.7 a	0.05	4.5 b	0.04	4.5 b	0.06
K_{232}	1.71 a	0.02	1.68 b	0.01	1.66 b	0.02
K_{270}	0.12 a	0.00	0.12 a	0.00	0.10 b	0.01
IT	15.2 c	0.4	18.2 b	0.3	19.1 a	0.5
TP	213 c	43	382 b	28	445 a	20
SS	6.4 c	0.2	7.9 b	0.1	8.7 a	0.2
2001/2002						
A	0.33 ns	0.04	0.30 ns	0.02	0.31 ns	0.02
PV	6.0 b	0.07	5.8 c	0.05	6.1 a	0.06
K_{232}	1.83 b	0.01	1.84 a	0.02	1.82 ab	0.02
K_{270}	0.14 a	0.00	0.12 b	0.01	0.14 a	0.00
IT	15.4 c	0.5	18.2 b	0.7	19.2 a	0.5
TP	235 b	43	399 a	59	447 a	21
SS	7.0 c	0.2	7.6 b	0.2	8.4 a	0.3
2002/2003						
A	0.25 ns	0.01	0.26 ns	0.02	0.24 ns	0.02
PV	5.5 b	0.04	5.3 c	0.05	5.6 a	0.04
K_{232}	1.71 ns	0.03	1.75 ns	0.01	1.73 ns	0.02
K_{270}	0.12 a	0.00	0.11 b	0.00	0.11 b	0.01
IT	15.8 c	0.8	17.7 b	0.8	18.8 a	0.3
TP	237 b	39	388 ab	38	418 a	46
SS	6.2 c	0.2	6.8 b	0.2	8.2 a	0.2

Data represents mean value (*m*) and standard deviation (SD).
Significant differences in the same row are showed by different letters ($p < 0.05$).
Abbreviations: SM, stone mill; DS, de-stoner; DH, de-stoner equipped with a heat exchanger; A, acidity (% of oleic acid); PV, peroxide value (meq of oxygen/kg of oil); IT, induction time (h at 120 °C); TP, total phenols (mg/kg); SS, sensory score.

the stone mill was used to prepare the paste, the oils extracted contained much lower amounts of polyphenols (213 ± 40 mg/kg) than the oils obtained using the de-stoner, with or without a heat exchanger (449 ± 32 and 372 ± 42 mg/kg, respectively). These variations were statistically different in both cases ($p < 0.001$). The amount of polyphenols was approximately twice as high in the oils obtained employing a heat exchanger as the oils obtained with the employment of the stone mill. This amount was higher in comparison with the oils obtained using only the de-stoner with an average difference of about of 15%. Also this last difference is statistically significant ($p < 0.001$). The introduction of a heat exchanger in the industrial plant gives rise to the instantaneous attainment of the temperature of the malaxation (27 °C) and have a positive effect on the total phenol content. In fact also Ranalli, Contento, Schiavone, and Simone (2001) found that the content of phenols increased progressively as the kneading temperature increased.

The results obtained employing the de-stoner machine confirms previous researches (Amirante et al., 2002; Amirante et al., 2001; Servili et al., 2000). In fact, oil mechanical extraction from de-stoned pastes can improve the oil phenolic concentration and it seems to confirm the relationships between the control of oxidative reactions during processing and the phenolic concentration in the oil because of the peroxidase is highly concentrated in the olive seed. The de-stoning process, excluding the olive seed before malaxation, partially remove the peroxidase activity in the pastes and consequently can reduce the enzymatic degradation of the hydrophilic phenols in the oils during the process thus improving their concentration and oil oxidative stability (Servili et al., 1999).

The antioxidant activity of hydrophilic phenols of virgin olive oil has been well studied (Servili et al., 2004). In fact, as reported by different authors, the concentration of phenolic compounds, evaluated colorimetrically and expressed as total phenols, was highly correlated to the shelf life of virgin olive oil, tested using accelerated methods such as Rancimat (Gutierrez Gonzales-Quijano et al., 1977; Ranalli, Malfatti et al., 2003). The results of the Rancimat test are shown in Table 1. The mean value of Rancimat induction times (h at 120 °C) of the samples obtained in the three crop seasons employing the de-stoner equipped with the heat exchanger was about 25% higher than stone mill oil ($p < 0.001$) and only about 5% more in comparison to the de-stoned samples extracted without the heat exchanger ($p < 0.05$). Fig. 3 relates the total phenols data to the corresponding induction times for the oils of the three extraction systems. The overall values show that a direct correlation exists between the two parameters. The regression line computed yielded $r^2 = 0.90$ ($p < 0.001$). Frega, Gagliotti, and Mozzon (1997) also reported that stone removal gives rise to an increase in oxidative stability in the oils.

3.4. Aromatic fraction

Olive oil volatile compounds are produced from polyunsaturated fatty acids through the cascade of reactions collectively called "the lipoxygenase pathway". The lipoxygenase pathway involves the oxidative degradation of the polyunsaturated linoleic and α-linolenic acids, which are split into volatile C_6 or C_9 carbonyl fragments. These fragments can be further modified by isomerisation, reduction and esterification and the variety of volatile compounds thus produced will constitute the volatile fraction of the oil, so this pathway plays an important role in the case of olive oil from the point of view of its quality. In the case of olive oil, in fact, the lipoxygenase pathway is principally triggered during the crushing of olive fruits and the malaxation of the resulting paste that takes place in the extraction process. Thus, the aroma of a given oil will be a function of the activity levels and characteristics of the enzymes involved in that cascade of reactions (Angerosa et al., 2004). This pathway has been detected in the particulate fraction of olive fruit pulp (Salas, Williams, Harwood, & Sanchez, 1999). Some of the major volatiles of olive oil that arise from lipoxygenase pathway include C_5 and C_6 compounds (Gardner, 1991; Hatanaka, 1993; Hatanaka, Kajiwara, & Sekiya, 1987; Olias, Pérez, Rios, & Sanz, 1993). Unsaturated six carbon aldehydes and alcohols sensory qualities are related to the so-called "green odour" (Hatanaka, Kajiwara, Horino, & Inokuchi, 1992). Thus, it can be inferred that the presence of these compounds in good quality virgin olive oils is critical to provide the fresh "green notes" typical of these oils (Morales & Aparicio, 1999).

Our attention in this study was directed to these C_5 and C_6 compounds that already been identified as responsible for positive odour properties. In fact, to

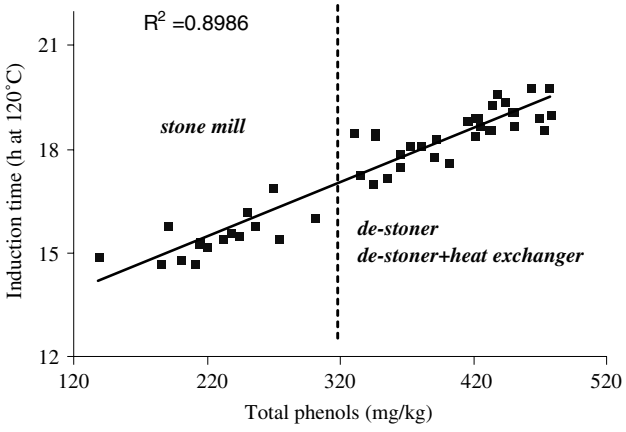

Fig. 3. Correlation between total phenols and induction time.

the aroma of high quality oil, in addition to fruity, generally contribute the "green" sensation reminiscent of just cut grass, leaf, tomato, artichoke, walnut husk, apple or other fruits.

The C_5 and C_6 volatile compounds are evaluated by a GC-MS purge and trap system. In all of the extra virgin olive oil analyzed we considered the presence of six C_5 and C_6 components, with retention times ranging between 42.0 and 60.5 min. All the chromatograms for each samples were similar, with differences relating only to the peak areas and mainly ascribable to the different olive paste preparation technique used. The peaks were identified by comparing the retention time of each peak with that of the corresponding standard. A typical GC-MS profile of aromatic volatile fraction of virgin "Coratina" olive oil is giving in Fig. 4.

Table 2 summarizes, as average of three crop seasons, the trend of volatile compounds with respect to the different paste preparation techniques.

In order to determine the influence of three different paste preparation techniques volatile on these C_5 and C_6 compounds of olive oil, the trials were planned by using homogeneous batches of fruits of the Coratina variety, fixing the same time and temperature of olive paste malaxation in a watertight mixer, and setting up the same process parameters of the decanter, so that any modification of flavour, and consequently of concentrations of volatile compounds, had to be exclusively attributed to the different paste preparation techniques. Total amount of the volatile compounds considered was substantially positive influenced by the de-stoner and by the introduction of a heat exchanger. The employ of de-stoner produced oils characterized by a higher amount of pleasant volatile compounds, especially of *trans*-2-hexenal, hexanal and *cis*-3-hexen-1-ol compared with the concentration of the same compounds in oils obtained with the same processing diagram except for the crushing performed by means of a stone mill. These differences increase with the introduction of the heat exchanger.

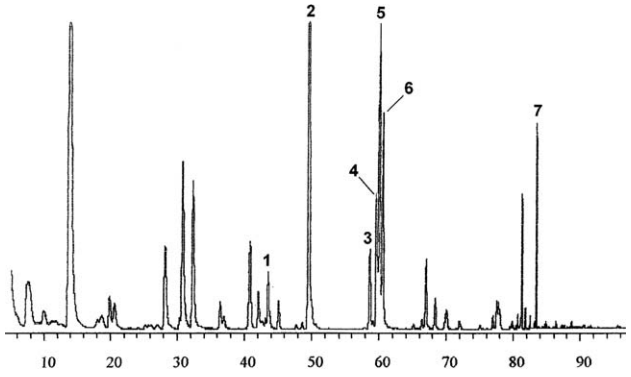

Fig. 4. GC-MS profile of the aromatic volatile fraction of a virgin olive oil of the cultivar "Coratina". Peaks identified: (1) *cis*-2-Penten-1-ol, (2) Hexanal, (3) *cis*-3-Hexen-1-ol, (4) 1-Hexanol, (5) *trans*-2-Hexen-1-ol, (6) *trans*-2-Hexenal, (7) nonan-1-ol (internal standard).

In 2001 Angerosa, Basti, Vito and Lanza, found that some modifications of the concentration of C_5 and C_6 compounds from the lipoxygenase pathways should be attributed to changes of operative conditions adopted during the oil extraction process. Almost all volatile compounds of a good quality olive oil give rise at the moment of tissue disruption of the olive pulp, therefore the effectiveness of crushing plays an important role in their production. The use of an hammer mill crushers (Angerosa & Di Giacinto, 1995), which determining a more violent grinding of pulp tissues causes an increase of the olive paste temperature and the reduction of hydroperoxide lyase activity (Salas & Sánchez, 1999a; Salas & Sánchez, 1999b), has as a consequence the production of oils characterized by a lower amount of volatile compounds, especially of *trans*-2-hexenal, hexanal and *cis*-3-hexen-1-ol, compared with the concentration of the same compounds in oils obtained with the same processing diagram except for the crushing performed by means of a stone mill (Angerosa & Di Giacinto, 1995). In our experiences the employing of the de-stoner, instead of the hammer crusher, does not cause an increase of the olive paste temperature. The de-stoner, in fact, is composed from a cylindrical perforated stationary grill and a rotary shaft. The olives are pushed from the centrifugal force towards the perforated grill. The olive tissues cross the grill and the kernel remains inside of the cylinder. In this condition the grinding of

Table 2
Amounts of C_6 and C_5 compounds from lipoxygenase pathway determined in virgin olive oil from three different paste preparation techniques

Volatiles compound (mg/kg)	Stone mill		De-stoner		De-stoner + heat exchanger	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Hexanal	8.1 c	0.4	13.5 b	0.3	19.4 a	1.2
trans-2-Hexenal	110.8 c	1.8	185.4 b	6.1	305.4 a	6.2
1-Hexanol	10.4 c	1.1	39.5 a	2.9	26.5 b	2.8
trans-2-Hexen-1-ol	12.6 b	0.5	14.6 a	0.4	12.7 b	0.5
cis-3-Hexen-1-ol	4.8 c	0.5	8.6 b	0.4	10.8 a	0.5
cis-2-Penten-1-ol	0.5 b	0.4	2.1 a	0.2	2.5 a	0.3

Data are expressed as mg/kg of nonal-1-ol (internal standard) and are means of three harvesting years (five replication for each season). Significant differences in the same row are showed by different letters ($p < 0.05$).

pulp tissues is less drastic than the hammer crusher and the lipoxygenase enzymatic system is not damaged from an increment of temperature of the olive paste that to the end of the process arrived to about 18–20 °C.

The introduction of a heat exchanger in the industrial plant gives rise to the instantaneous attainment of the temperature of the malaxation (27 °C) and have a positive effect on the generation of volatile compounds. In fact we have observed that there are significant differences between the oils obtained. The tests highlighted that when the stone mill was used to prepare the paste, the oils extracted contained much lower amounts of volatiles compounds than the oils obtained using the de-stoner, with or without a heat exchanger. These variations were statistically different in both cases ($p < 0.001$).

Luaces, Pèrez, and Sanz (2003) also confronted the aroma composition of olive oils from fruit pulp and wounded fruit (olive pulp plus stones). They found that seed presence during the olive oil extraction process produced a decrease in the content of C_6 compounds in both green and ripe fruits. Olive seeds have a effective role of in the biosynthesis of olive oil aroma through the lipoxygenase pathway during the extraction process to produce virgin olive oil. Olive seeds, in fact, should contain enzymatic activities metabolizing 13-hydroperoxides other than hydroperoxide lyase, giving rise to a net decrease in the content of C_6 unsaturated aldehydes during the olive oil extraction process.

To carry instantaneously the temperature of the paste to the kneading value is equivalent to extend the malaxation time of an interval equal to the time that the mixer employs to heat all the olive paste mass. The influence of malaxation time on volatile profile and therefore sensory characteristics of resulting oil was just studied (Angerosa, D'Alessandro, Basti, & Vito, 1998; Ranalli, Pollastri, Contento, Iannucci, & Lucera, 2003). Angerosa, Mostallino, Basti, and Vito (2001) found that the increase of alcohols and of C_6 and C_5 carbonyl compounds, especially of hexanal, represents an important contributor to the olive oil flavour, is the main effect of the malaxation time. Ranalli, Gomes et al. (2003), Ranalli, Malfatti et al. (2003), Ranalli, Pollastri et al. (2003) and Ranalli, Pollastri, Contento et al. (2003) found that the total volatiles and green volatiles of the lipoxygenase cascade (C_6 aldehydes, C_6 alcohols, C_5 alcohols and C_5 carbonyls) increased progressively with increasing malaxing times. The sensory analysis highlights a weakening of typical "green" attributes with the prolonging of malaxation time. Our results confirms this observation.

3.5. Sensory analysis

The tests highlighted that when the stone mill was used to prepare the paste, the oils extracted had a lower sensory score than the oils obtained using the de-stoner, with or without a heat exchanger. The heat exchanger employing produces oils rich in volatiles compound with the higher sensory score that have a superior market value. Little amount of these oils improves large quantities of oils poor in pleasant sensory perceptions and taste, increasing the market value of ordinary oil.

4. Conclusion

The oils obtained from de-stoned pastes had a higher polyphenol content in comparison with the oils obtained from whole paste. The increment of the amount of phenolic compounds determined an increase of induction time to the oxidation. A significant correlation has been found between the content in total phenols and the induction time. The de-stoned oils had a higher amount of C_5 and C_6 volatile compounds, responsible of positive notes of the flavour, in comparison with the oils obtained by stone-mill. This increment is due to the removal of the seeds that should contain enzymatic activities metabolizing 13-hydroperoxides other than hydroperoxide lyase, giving rise to a net decrease in the content of C_6 unsaturated aldehydes during the olive oil extraction process. The de-stoner oil had a higher sensory score than the traditional one and consequently a higher market value. The de-stoner is a soft technique of olive paste preparation that guarantees the highest amount of phenols and volatile compounds. The use of the heat exchanger coupled to the stoner improves the olive oil yields and it renders the malaxation more efficient. Therefore its introduction could optimize the effect of the malaxation reducing the ratio between the exchange thermal surface and the mass. Other tests must be conduct on other varieties in order to verify the influence of the innovative technology of olive oil extraction on the variety.

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