Effect of Fruit Stoning on Olive Oil Quality

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ABSTRACT: Stoning olives has been proposed as an alternative to crushing the whole fruit during the oil extraction process. Seven pairs of oils obtained from stoned and nonstoned olives from five different cultivars were evaluated to determine the effect of the proposed technology on oil quality. The main organoleptic and physicochemical parameters as well as resistance to oxidation showed no obvious influence of stoning on oil quality. Chemometric analysis of the data showed the oils grouped more according to genetics (cultivar) than to technology. Lipoxygenase activity in the paste from whole and stoned olives showed no effect that could be attributed to the technology. Furthermore, the stone did not contribute significantly to increasing the lipoxygenase activity in the olive paste.

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KEY WORDS: Cultivar, extraction process, olive oil, quality, stoned fruit.

Olive oil consumption is steadily increasing worldwide, owing not only to its nutritional-health characteristics but also to its particular organoleptic properties that make it unique in the "food fats" sector. The aim of obtaining a high-quality product has stimulated the search for technological innovations, which, nevertheless, must be carefully evaluated before being applied on an industrial scale.

The value of extra virgin olive oil, like every other product of agro-food processing, depends on maintaining and highlighting the characteristics of the raw material. It is impossible to obtain an excellent product by starting with poor raw material, even if the most efficient extraction procedures are used. The cultivars (1) and the harvest time must be selected carefully to correspond with to the optimal level of fruit maturity. The extraction process also affects the quality of the product. In fact, in starting with the same raw materials, it is possible to obtain oils with different organoleptic and physicochemical characteristics, even with defects, if the operating conditions are not optimal (2). The currently used extraction processes, both traditional and continuous, require grinding of the whole olives and malaxation of the paste, followed by separation of the oil from the solid parts of the fruit and from the vegetation water by centrifugation. In the so-called complete system, this separation takes place directly in the decanter. A new technology has been proposed that calls for removing the stone from the fruit before grinding (3). This is followed by malaxation of the pulp only, which is more liquid and homogeneous. The final step is separating the oil from the other components by decanter, although at present the oil yield is smaller than that obtained with the traditional system (4). Interest in extracting oil from stoned paste has arisen primarily from a technological consideration. The substitution of the disc or hammer grinder by a stoner coupled with a finisher should allow the plant working capacity to be increased and the energy consumption to be decreased owing to less friction during the working (3). With regard to oil quality, some authors (5,6) believe that the stoning process reduces the risk of oxidation and improves the organoleptic quality of the final product. It has been hypothesized that these effects could be associated with the absence of the stone in the paste during grinding. In fact, the stone is rich in oxidative-type enzymes (lipoxygenases: LOX) and behaves as a very active biological material in the catalysis of oxidative reactions (7).

However, studies related to LOX activity of the paste with and without the stone have not been reported, nor has an exhaustive study been carried out on the antioxidant and volatile compounds present in extra virgin olive oil from whole and stoned olives. The aim of the present work was to evaluate the effect of stoning on the oxidative state of oils obtained from the 1999/2000 harvest and to study the level of antioxidant and volatile compounds. The basic physicochemical parameters used to define extra virgin olive oil quality were measured as well.

MATERIALS AND METHODS

Plant material and oil extraction. The oils were obtained from the healthy fruits of five cultivars from the Carboi experimental field (Menfi) of the Ente di Sviluppo Agricolo (E.S.A.) of Sicily (Table 1). At harvest, fruit maturity was evaluated by the degree of pigment change of the epidermis (Table 1) in a subsample of 100 fruits (8). The fruit was harvested at two different stages of maturity for cultivars Nocellara del Belice and Moresca only. For each cultivar, the fruits were separated into two subsamples of 50 kg, one of which was stoned with a stoner (SR 100; Toscana Enologica Mori, Florence, Italy) and ground immediately in an hammer mill (Oliomio 50; Toscana Enologica Mori). The paste underwent malaxation at 25°C for 30 min, and the oil was extracted with a two-phase decanter. Samples of the malaxed paste with and without stones were frozen in liquid nitrogen and stored at −80°C for future enzymatic extraction.

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TABLE 1
Cultivars, Degree of Ripening, and Technological Condition of the Fruits Whose Oils Were Studied[a]

Cultivar	Degree of ripening	Fruit treatement	Sample
Nocellara del Belice	100% yellow-green	Whole	NBw100yg
Nocellara del Belice	100% yellow-green	Stoned	NBs100yg
Nocellara del Belice	40% color change	Whole	NBw40cc
Nocellara del Belice	40% color change	Stoned	NBs40cc
Moresca	100% yellow-green	Whole	Mw100yg
Moresca	100% yellow-green	Stoned	Ms100yg
Moresca	80% color change	Whole	Mw80cc
Moresca	80% color change	Stoned	Ms80cc
Nocellara Etnea	100% yellow-green	Whole	NEw100yg
Nocellara Etnea	100% yellow-green	Stoned	NEs100yg
Cerasuola	70% color change	Whole	Cw70cc
Cerasuola	70% color change	Stoned	Cs70cc
Biancolilla	80% color change	Whole	Bw80cc
Biancolilla	80% color change	Stoned	Bs80cc

[a]All fruits were harvested from the Carboi experimental field (Menfi) of Ente di Sviluppo Agricolo of Sicily.

Determination of the free acidity, peroxide number, and UV extinction coefficient. The determination of these parameters was done according to official methods (EEC regulation no. 2568/91) (9).

Oxidative stability of oils. Oxidative stability was evaluated as induction time (h) of the peroxidizing reactions using 5 g of oil sample and a Rancimat 679 apparatus (Metrohm Co., Basel, Switzerland) (10).

Extraction and determination of total phenols and o*-diphenols.* Twenty grams of oil was added to 10 mL of a water/methanol solution (80:20 vol/vol) and shaken for 20 min with a mechanical shaker. The sample was then centrifuged at $2000 \times g$ for 10 min to separate the aqueous MeOH phase. The extraction was repeated a second time with the same procedure. The two aqueous MeOH phases were combined and the total phenols were determined by spectrophotometry using the Folin–Ciocalteau method (11). The amount of total phenols was calculated from a calibration curve made using standard solutions of 10 to 800 mg/L gallic acid (Sigma-Aldrich, St. Louis, MO).

Ortho-diphenols were determined colorimetrically with Arnow's reagent (equimolar $NaNO_2 + Na_2MO_4$), which develops a pink color with a maximum absorbance at 450 nm (10).

Qualitative analyses of phenolic compounds. The phenolic extract, obtained as just indicated, was blown with a N_2 flow to evaporate the methanol. The aqueous residue was freeze-dried and resuspended in 500 µL of a MeOH/H_2O (80:20 vol/vol) solution. The concentrated sample was then analyzed using HPLC (10). The amounts of the individual phenolic substances were determined using a calibration curve made from 10 to 800 mg/L of gallic acid. Phenolic compounds were identified by retention time of phenolic standards. Some of these (tyrosol, vanillic acid, caffeic acid, syringic acid, *p*-coumaric acid, ferulic acid, and coumaric acid) were purchased from Sigma-Aldrich whereas hydroxytyrosol, oleuropein, aglycones, and elenolic acid were obtained from oleuropein by biotransformation (12).

FA determination. An amount of oil equal to 0.3 g was added to 4 mL of hexane and 400 µL of a methanol solution of 2 M KOH. After vigorous shaking for 1 min, the hexane phase containing methylated FA separated and that phase was then analyzed by GC (10).

Analysis of volatile compounds. The analytical determination of the volatile compounds was carried out according to the static headspace (HS) technique using a PerkinElmer Model HS 40 XL automatic sampler under the following operating conditions: Vials containing 10 mL of oil were heated for 45 min at 80°C; the temperature of the needle and that of the transfer line were 130 and 200°C, respectively. The helium in the vials was kept under pressure for 0.3 min, while that of the injector was 0.25 min. To separate the individual volatile compounds, an Auto System XL PerkinElmer gas chromatograph was used with a Stabilwax capillary column (60 m, 0.25 mm i.d., 0.25 µm df) and a FID at 250°C. Helium was used as the carrier gas at a pressure of 26 psi, and hydrogen and air were at 45 and 450 mL/min, respectively. Injection temperature was 200°C; the heating program of the GC oven column started at 40°C for 5 min, with an initial gradient of 2°C/min up to 70°C and a second gradient of 4°C/min to 160°C and hold for 15 min.

Identification of the volatile compounds was carried out by comparison to the retention times of standard compounds (Sigma-Aldrich) added to refined oil. The quantitative determination was obtained by using the hexanol calibration curve from 0.02 to 100 mg/L and comparing the concentrations of all the compounds to it.

Organoleptic evaluation of oils. The organoleptic evaluation of oil was carried out according to the methodology of the International Olive Oil Council (COI) (13,14) incorporated as

well in the E.C. regulation (15), in which both defect and merit intensities of oils are reported on a conventional scale from 0 to 10 cm. The initial point of the linear scale (0 cm) represents the absence of the organoleptic characteristics analyzed, whereas the final point (10 cm) represents the highest value in the evaluation of a given set of oil standards according to the International Olive Council.

Enzymatic analysis. The extraction and enzymatic assay of whole or stoned paste, olive pulp, and embryo were carried out as described previously (16).

Statistical analysis. Since the aim of this work was to verify the effect of the technology on oil quality, we considered two theses (olives with and without stones) while the replicates were the 14 oil samples or pastes. The analytical data were submitted to principal components analysis (PCA), able to describe the structure of a series of data using a model of least dimension (17). In other words, PCA is an instrument that can transform a table of data into informative diagrams that illustrate the projection of points on the model and the existence of possible subgroups. The program used, containing the PCA method, was SIMCA-P (18) version 8.0 by Umetrics AB (Tmeå, Sweden).

RESULTS AND DISCUSSION

The study was conducted on two different types of oil from the same cultivar, using the parameters to define extra virgin olive oil quality to evaluate the effect of the stoning process. Table 2 reports the data of the most common analytical parameters of the oils: free acidity, peroxide number, and UV absorbance, together with the amounts of phenolic substances and the time of oxidation induction, evaluated using the Rancimat Test. Most of the samples had a free acidity not greater than 0.5% free oleic acid. Only the pairs of oils from the cultivars Biancolilla and Moresca (harvested when the fruit color change was 80%) were unsatisfactory regardless of the processing technique used, even though the free acidity was less than the legal limit of 1%. The peroxide number for these two pairs of oils was rather high and in the case of Biancolilla, it was close to the maximum allowed for the classification as extra virgin. For all the other pairs of oils, the peroxide number was low and showed no effect on the state of hydroperoxidation of the lipid material due to stoning.

The values of UV absorbance of the oils showed no difference due to the presence or absence of the stone (Table 2). Also, the pairs of oils from cv. Biancolilla had K_{232} absorbance values, higher than the limit allowed by EEC Regulation no. 2568/91 for classification as extra virgin olive oil. This spectrophotometric absorbance value indicates the presence of conjugated dienes and therefore a high state of oxidation of the lipid material. This negative characteristic may be related to alterations caused by an advanced degree of fruit maturation and to the low amount of phenolic substances, which can cause the low resistance of oil to oxidation reported by some authors (19). The ΔK values of all the oils were within the limits set by law and showed no differences between stoned and nonstoned oils.

The amounts of phenolic substances in the oils (Table 2) show differences not only in relation to variety but also within

TABLE 2
Free Acidity, Peroxide Number, Total Phenols, *o*-Diphenols, Spectrophotometric Indices, and Racimat Test of Oils Obtained from Two Different Extraction Systems

Sample[a]	Oil yield (% FW[b])	Free acidity (calculated as oleic acid, g%)	Peroxide number (meq O_2 kg^{-1})	Polyphenols[c] (mg kg^{-1})	*o*-Diphenols[d] (mg kg^{-1})	1% K_{232} (1 cm)	1% K_{270} (1 cm)	ΔK	Rancimat test (h)
NBw100yg	17.4	0.23	5.6	183	54	0.4	0.03	0.024	8.7
NBs100yg	15.8	0.38	4.5	140	36	0.7	0.07	0.001	6.7
NBw40cc	18	0.25	3.5	169	48	0.4	0.05	0.001	6.9
NBs40cc	15.2	0.22	3.7	194	49	0.9	0.18	0.005	8.2
Mw100yg	18.04	0.34	5.5	115	29	1.7	0.15	0.003	5.0
Ms100yg	15.8	0.41	7.6	126	33	1.4	0.08	0.001	5.0
Mw80cc	19.1	0.76	12.9	119	45	2.1	0.12	0.002	3.5
Ms80cc	17.5	0.71	9.0	130	48	1.7	0.09	0.001	4.9
NEw100yg	15.6	0.44	7.0	189	29	1.8	0.10	0.002	5.8
NEs100yg	13	0.43	6.4	172	24	1.5	0.09	0.001	6.1
Cw70cc	19.7	0.23	5.6	251	88	1.5	0.18	0.001	8.7
Cs70cc	17.3	0.20	4.8	272	94	1.4	0.14	0.001	9.5
Bw80cc	17.5	0.64	17.1	47	39	3.1	0.17	0.004	2.7
Bs80cc	15.6	0.86	19.9	33	28	3.4	0.19	0.007	2.0

[a]For sample codes see Table 1.
[b]FW, fresh weight.
[c]The data represent the means of three measurements ($LSD_{0.05}$ 16), where LSD = least squares difference.
[d]The data represent the means of three measurements ($LSD_{0.05}$ 7).

the individual pairs of oils. In the latter case, the difference cannot be attributed to the different system of working the olive, for the oils coming from stoned fruits had both higher and lower amounts of phenolic substances than those obtained with the whole fruit. The differences in the amounts of polyphenols within the pairs of oils could be due to different partitioning of the polyphenols between the water and oil during the separation process or to oxidation during malaxation that could cause differences even with standard operating conditions (time and temperature of malaxation of 30 min and 25°C).

The concentration of phenolic substances was correlated to the resistance of the oil to rancidity, in agreement with Frega *et al.* (19). The Rancimat test showed that wherever a high amount of polyphenols was found, the time of resistance to forced oxidation was greater. However, for oxidative resistance, there were no differences between oils extracted from the pulp only and those obtained from the whole fruit. This is not in agreement with Frega *et al.* (19), who compared pairs of oils from cultivars Frantoio and Moraiolo and found destoned oil had a higher resistance to forced oxidation. They attributed the greater stability to the hypothesis that during grinding and malaxation, the contact of oil of the pulp with the embryo present in the stone causes a series of enzymatic reactions, among which are the oxidative ones (LOX), that influence the shelf life of the product.

The results reported in Table 2 were analyzed by PCA. The total variance explained by three principal components was 91%. The first eigenvector explained 60%, the second 19%, and the third 12%. In Figure 1 the resulting plot provides no evidence of groupings as a function of the technology used for the oil extraction. In the score-plot the oils seem to cluster in relation to the cultivar. The only purpose of the ellipses inserted in Figure 1 is to visualize the oil samples pertaining to the same cultivar.

Since differences were not noted between the oil pairs with respect either to the oxidative state of the TG or to storage time, a study on the activity of the LOX in the enzymatic extracts obtained from the two types of paste was undertaken to determine if and how much the stone increases the LOX activity (EC 1.13.11.12). LOX are a group of enzymatic proteins that can oxidize free PUFA that are characterized by a (*Z,Z*)-1,4 pentadienic system (linoleic, linolenic, arachidonic acids) resulting in the respective hydroperoxides (20). The spectrophotometric data related to the specific activity of LOX, reported in Figure 2, show no significant differences ($P = 0.01$) between the pastes from de-stoned and whole olives. However, there is a diversity with regard to variety and level of fruit coloration. The highest enzymatic activity was recorded in 100% green fruit, in agreement with Salas *et al.* (21), and the activity decreased as the fruit matured. To determine how much the stone contributed to LOX activity, the enzyme was determined in enzymatic extracts obtained from the pulp and from the stone alone in 100% yellow-green olives. The results showed that the specific activity of LOX in the stone was about one-tenth of that measured in the pulp (Patumi, M., S. Terenziani, and M. Ridolfi, unpublished data). In considering these results, it can be concluded that the stone does not contribute significantly to increasing LOX activity and that stoning will not change the shelf life of the oil produced.

The oils were analyzed by GC to determine the FA composition (Table 3). Even if the acidic composition of the endosperm is different from that of the pulp, the FA composition of the pairs of oils analyzed did not differ as a result of the stoning technique. There were marked differences in the 18:1/18:2 ratios with respect to the cultivars examined, particularly between Nocellara del Belice, Moresca, and Biancolilla, and with respect to the level of maturity of the fruit. In the first two cultivars, where two stages of maturity were evaluated, the 18:1/18:2 ratio decreased as fruit maturity increased.

The concentrations of the aromatic substances found in the headspace of the oil are reported in Table 4. Overall, there were

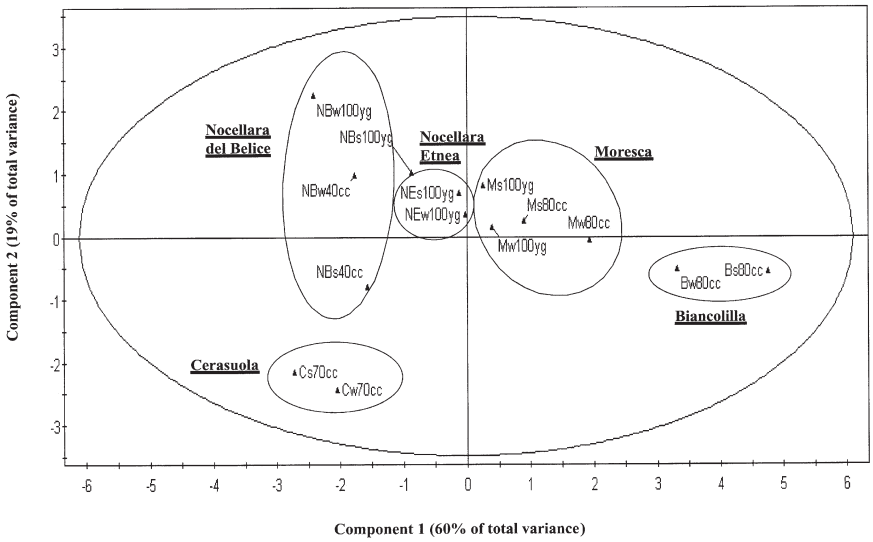

FIG. 1. 2-D plot showing the result of principal component analysis of the free acidity, peroxide number, total phenols, *o*-diphenols, spectrophotometric indices, and Rancimat test.

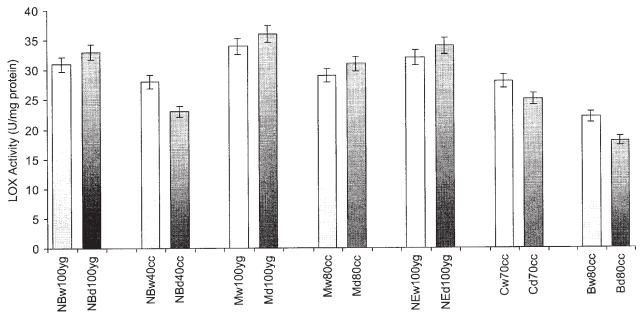

FIG. 2. Lipoxygenase (LOX) activity in pastes from whole (open bars) and stoned (solid bars) olives. Data represent the means of three measurements (± SD).

no differences in the values of the pairs of different cultivars with the exception of Moresca and Nocellara del Belice (both with 100% yellow-green fruit), in which the total and C_6 aromas were greater in the stoned olive oil according to Angerosa *et al*. (6). As already noted (22), the quantity of total volatile substances decreased within the same variety (Nocellara del Belice and Moresca) with increased fruit maturity.

The six-carbon aldehydes and alcohols, believed by some authors to be directly correlated to LOX activity (23), followed the foregoing trends. There were no variations attributable to the presence or absence of stones in the paste, but there were differences between cultivars. (*E*)-2-Hexenal, believed to be the aldehyde responsible for green odor notes, was present in the oils in variable quantities regardless of the type of paste used.

In the same way, qualitative analysis of the phenolic substances (data not reported) showed some variation based on variety. The aromatic substances (Table 4) and phenolic compounds were used in the chemometric analyses. The results (Fig. 3) clearly show a differentiation that groups the oils with respect to varietal origin rather that to the use of whole or stoned olives. The substantial compositional uniformity of the oils also was confirmed by a taste panel, carried out according to COI methods (Table 4). No differences were noted between the oil pairs. The only differences noted were between the cultivars and the degree of fruit maturity. In accord with what has already been indicated in the data reported in Table 2, the oils obtained from the two types of extraction processes from Moresca and Biancolilla (80% color change) had defects of fustiness and rancidity, even if slight.

There were no differences between the oils from whole or stoned paste, and only limited differences attributable to the cultivars examined and the level of fruit maturity. Minimal differences, not always attributable to one or the other type of oil, were observed in the content of aromatic compounds and the quantities of phenolic substances. There were clear differences with respect to the analytical parameters examined for the different cultivars, confirming the importance of genetic factors in the physicochemical and organoleptic characteristics of the oil, as well as that of the degree of fruit ripeness.

The technology of extracting oil from stoned olives, proposed by oil machine companies and recently supported by some researchers, does not lead to a net qualitative advantage in the amount of extra virgin olive oil obtained from stoned olives. Since the activity of the LOX enzyme plays a fundamental role in controlling oil oxidation as well as in forming aromatic compounds, and since the results of this study

TABLE 3
FA Composition of the Oils Extracted Using Two Different Operating Systems

Oil sample[a]	16:0 (%)	16:1 (%)	17:0 (%)	17:1 (%)	18:0 (%)	18:1 (%)	18:2 (%)	18:3 (%)	20:0 (%)	20:1 (%)	UNS/SAT[b]	MONO/POLY[b]	18:1/18:2
NBw100yg	13.6	1.0	0.1	0.1	3.1	73.2	7.9	0.6	0.4	0.2	4.86	8.77	9.23
NBs100yg	12.8	0.9	0.1	0.1	3.5	73.5	7.7	0.7	0.6	0.3	4.91	9.01	9.61
NBw40cc	12.1	1.0	0.1	0.1	3.1	72.2	10.0	0.7	0.5	0.3	5.38	6.87	7.22
NBs40cc	13.3	1.2	0.1	0.1	2.9	71.5	9.9	0.5	0.4	0.2	5.04	6.98	7.21
Mw100yg	14.6	1.6	0.1	0.5	2.2	69.2	10.4	0.8	0.4	0.3	4.78	6.40	6.63
Ms100yg	14.7	2.0	0.2	0.3	2.2	68.3	10.9	0.7	0.4	0.2	4.68	6.10	6.28
Mw80cc	17.2	2.2	0.1	0.4	2.2	62.9	13.8	0.7	0.3	0.2	4.07	4.52	4.56
Ms80cc	17.0	2.2	0.1	0.3	2.2	63.4	13.5	0.7	0.4	0.2	4.09	4.68	4.72
NEw100yg	14.8	1.2	0.1	0.2	2.3	66.8	13.5	0.6	0.3	0.3	4.73	4.86	4.97
NEs100yg	15.0	1.1	0.1	0.3	2.2	66.1	13.9	0.7	0.3	0.3	4.69	4.66	4.77
Cw70cc	12.0	0.5	0.1	0.1	2.2	72.1	11.7	0.5	0.4	0.4	5.82	5.98	6.17
Cs70cc	12.4	0.6	0.1	0.1	2.1	71.6	12.0	0.6	0.2	0.3	5.76	5.76	5.95
Bw80cc	15.5	1.8	0.1	0.3	2.3	63.3	15.2	0.9	0.3	0.3	4.49	4.07	4.16
Bs80cc	16.2	1.7	0.1	0.2	2.2	63.2	15.0	0.9	0.4	0.3	4.34	4.14	4.23

[a]For sample codes see Table 1.
[b]UN/SAT, ratio of total unsaturated to total saturated FA; MONO/POLY, ratio of total monounsaturated to total polyunsaturated FA.

TABLE 4

Analysis[a] of the Volatile Compounds in the Headspace of the Oils Extracted Using Two Different Operating Systems. Medians of Organoleptic Attribute Intensities of the Oils from Whole and Destoned Olives

Volatile compounds		Olive oil sample[b]													
(ppm)		NBw100yg	NBs100yg	NBw40cc	NBs40cc	Mw100yg	Ms100yg	Mw80cc	Ms80cc	NEw100yg	NEs100yg	Cw70cc	Cs70cc	Bw80cc	Bs80cc
Ethyl acetate		0.00	0.00	0.00	0.63	0.00	0.27	0.00	0.13	0.03	0.00	0.00	0.43	0.00	0.00
3-Pentanone		0.68	0.35	1.34	0.00	3.38	0.79	1.02	1.13	0.41	0.54	0.35	0.45	0.66	0.38
Hexanal		0.17	0.20	0.19	0.10	1.03	1.69	0.38	1.08	2.93	1.96	0.19	0.35	0.66	1.06
Isobutyl alcohol		0.00	0.88	0.00	0.58	0.00	0.43	0.43	0.45	0.32	0.39	1.38	0.72	0.41	0.49
1-Penten-3-ol		0.42	0.20	0.38	0.37	0.26	0.30	0.30	0.00	0.39	0.25	0.25	0.50	0.63	0.35
Isoamyl acohol		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.44
(*E*)-2-Hexenal		0.81	1.03	0.28	0.14	0.77	0.48	0.27	0.34	0.32	0.38	0.76	0.72	0.20	0.26
1-Pentanol		0.64	0.76	0.16	0.32	0.12	0.22	0.18	0.66	0.45	0.62	0.66	0.79	0.31	0.24
(*E*)-2-Penten-1-ol		0.14	0.31	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.32
(*E*)-2-Heptenal		0.46	0.40	0.20	1.09	0.10	0.28	0.22	0.00	0.32	0.00	0.38	0.50	0.38	0.00
1-Hexanol		0.64	0.00	0.91	0.00	2.68	4.49	2.41	1.88	1.34	0.00	1.36	1.22	1.93	1.11
(*E*)-3-Hexen-1-ol		0.00	0.00	0.40	0.24	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(*Z*)-3-Hexen-1-ol		3.77	7.79	3.21	2.68	1.32	4.53	2.88	3.26	2.27	4.78	4.30	3.99	3.60	3.41
(*E*)-2-Hexen-1-ol		0.00	0.17	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.38	0.00	0.00
(*E,E*)-2,4-Hexadienal		0.89	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.34	0.00	0.31	0.00	0.00
Acetic acid		0.92	0.32	0.28	0.36	0.47	0.32	0.21	0.18	0.31	0.00	0.24	0.00	0.32	0.43
ppm total		9.52	12.40	7.38	6.93	10.15	13.93	8.44	9.11	9.24	9.74	9.86	10.35	9.11	8.49
±SD[c]		0.45	0.59	0.35	0.33	0.48	0.66	0.40	0.43	0.44	0.46	0.47	0.49	0.43	0.40
ppm total C_6		6.27	9.18	4.99	3.58	5.82	11.32	6.08	6.57	6.86	7.63	6.60	6.96	6.40	5.84
(*E*)-2-Hexenal/hexanal		4.83	5.26	1.46	1.36	0.74	0.28	0.71	0.31	0.10	0.19	3.99	2.04	0.29	0.24
	Fruity	3.5	3.0	1.4	1.9	2.6	2.8			2.4	2.0	2.0	2.1		
Sensory	Bitter	1.7	1.4	1.8	1.4	1.2	1.2			1.4	1.7	2.4	2.2		
evaluation	Pungent	2.0	1.7	1.4	1.4	1.2	1.0			1.4	1.7	1.0	1.4		
(cm)	Defect							Fusty, rancid	Fusty, rancid					Fusty, rancid	Fusty, rancid

[a]Results are means of three determinations.

[b]For sample codes see Table 1.

[c]SD refers to the total amount of volatile compounds.

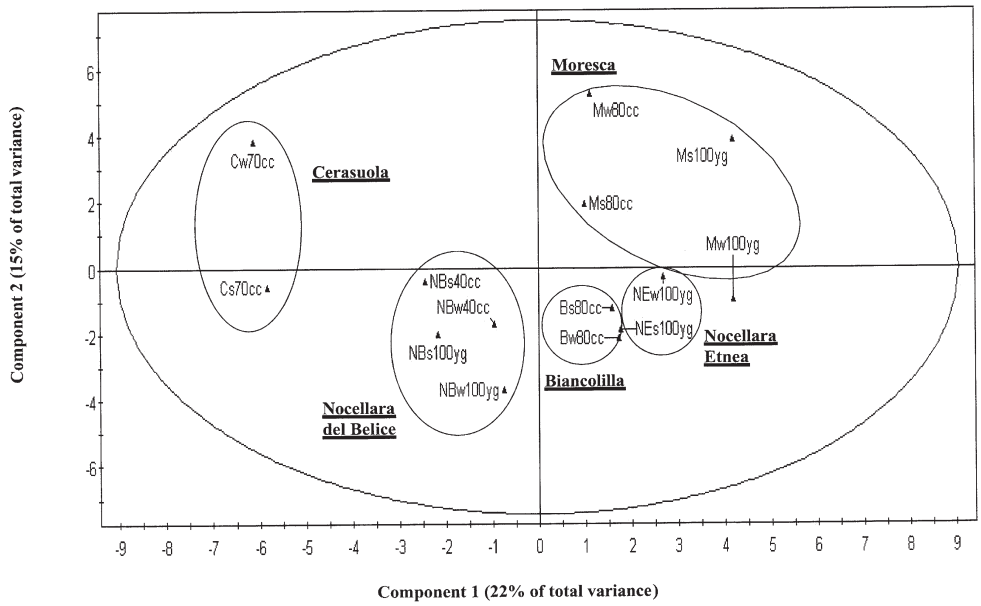

FIG. 3. 2-D plot showing the result of principal component analysis of the variables obtained from the HPLC analyses of the phenolic compounds and from the headspace–GC analyses of the volatile substances.

showed no difference between the LOX activity in whole and stoned olive paste, it can be concluded that stoning makes no difference.

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