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Characterization of aroma potential of apricot varieties using different extraction techniques

H.M. Solís-Solís [a], M. Calderón-Santoyo [a], S. Schorr-Galindo [b], G. Luna-Solano [c], J.A. Ragazzo-Sánchez [a,*]

[a] Laboratorio de Investigación en Alimentos, Instituto Tecnológico de Tepic, Av. Tecnológico No. 2595, C.P. 63175 Tepic, Nayarit, Mexico
[b] UMR 1212 Ingénierie de la Réaction Biologique-Bioproductions IR2B, Université de Montpellier II, Place E. Bataillon, 34095 Montpellier Cedex 5, France
[c] Instituto Tecnologico de Orizaba, Division de Estudios de Posgrado e Investigacion, Av. Oriente 9 No. 852, Orizaba, Veracruz, 94320, Mexico

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Abstract

Aroma compounds are presents in raw foods, freely and glycosidically-bounded (aroma precursors). In the present work, the volatile fraction of eight varieties of apricot were analyzed using simultaneous distillation extraction (SDE), solid phase extraction (SPE) with reverse phase (C18), liquid–liquid extraction (LLE) and headspace-solid phase microextraction (HS-SPME). The free aroma compounds were identified by GC–MS, finding common compounds such as linalool, α-terpineol, β-ionone and γ-decalactone and specific compounds due to the extraction method used. The ANOVA showed a significant effect in the extraction techniques and on the varieties in the free aromatic fraction from apricot as well. In spite of a large number of volatile compounds extracted by SPE, the technique that allowed for the most number of compounds to be extracted was SPME.

On the other hand, aroma potentials were evaluated. Chemical hydrolysis involved in SDE thermal treatments favoring the release of terpenes, aldehydes and lactones while phenol compounds, alcohols and ketones were released after the exogenous enzymatic hydrolysis.

Keywords: Aroma compounds; Aroma potential; Chemical hydrolysis; Enzymatic hydrolysis; Apricot; *Prunus armeniaca*

1. Introduction

The aroma, is one of the most significant and decisive parameters of quality in the election of a product. Aroma compounds are present in raw foods in free volatile form but also as non-volatile precursors such as substituted cystein sulfoxides, thioglycosides, glycosides, carotenoids, cinnamic acid derivatives (Crouzet, Chassagne, & Sakho, 1995).

Apricot fruits are appreciated by consumers for their flavor, sweetness and juiciness; these characteristics are strongly related to the variety and ripening stage at harvest (Botondi, DeSantis, Bellincontro, Vizovitis, & Mencarelli, 2003). The aroma is an integral part of the flavor, the aroma compounds of apricot have already been studied (Guichard & Souty, 1988; Guillot et al., 2006; Rodriguez, Seck & Crouzet 1980; Takeoka, Flath, Mon, Teranishi, & Guentert, 1990) gave a list of aroma compounds (AC) common to every variety analyzed. The major AC of this list are ethyl acetate, hexyl acetate, limonene, 6-methyl-5-hepten-2-one, menthone, E-hexen-2-al, linalool, β-ionone and γ-decalactone.

LLE is a direct extraction method in which the liquid sample and an organic solvent are in contact. The principle of the extraction is based on the solubility of the volatile compounds (VC) in the used solvent, which should have a different density than the water and immiscible in it. This current sample preparation using solvent combines different operation resulting in multistage operations that are laborious and time-consuming. The concentration step can introduce errors or losses of volatiles compounds. An

* Corresponding author. Fax: +52 311 211 94 04.
E-mail address: ragazzo@ittepic.edu.mx (J.A. Ragazzo-Sánchez).

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additional problem of this method is the solvent which should be eliminated introducing waste disposal.

In SPE, volatile compounds (VC) are adsorbed in a stationary phase for later to be selectively eluted with organic solvents. This method reduced limitation of LLE by using less solvent but it also needs multi-step operations and especially the concentration. The solid phases usually used are packed silica C18 (Engel & Tressl, 1983) and the Amberlite XAD-2 resine (Krammer, Winterhalter, Schwab, & Schereir, 1991).

SDE is a distillation system with a continuous extraction (Likens & Nikerson, 1964). This technique has been considered as the best isolation and recovery method of VC of a sample when it is applied appropriately, considering their possibilities and limitations, nowadays, this is the best choice for a high recovery for a wide range of compounds (Chaintreau, 2001). The major limitation to the use of this method is the thermal artifact it may cause.

The SPME technique has the following advantages: low cost, short time of extraction, simplicity, high selectivity and sensibility (Arthur & Pawliszyn, 1990; Gonçalves & Alpendurada, 2002). The SPME consists of a fused-silica fibre, coated with polymeric stationary phase introduced into a liquid or gas sample. The method involves two processes: the partitioning of the analytes between the coating and the sample and the thermal desorption of the analytes into gas chromatograph (Ibañéz, López-Sebastián, Ramos, Tabera, & Reglero, 1998).

The presence of glycosidically-bound aroma compounds in plants, and more particularly in fruits, including tropical fruits, has been reported (Boulanger & Crouzet, 2000). These glycosylated conjugates are considered to be potential aroma from which volatiles can be released by enzymatic or chemical hydrolysis during maturation, industrial pretreatment or processing of fruits (Boulanger & Crouzet, 2000; Crouzet et al., 1995). The aroma precursors constitute an important reservation of aroma compounds: this is the aroma potential (AP).

The glycosidically-bound compounds of apricot were studied in previous works (Crouzet et al., 1995; Guillot et al., 2006; Krammer et al., 1991; Salles, Jallageas, Fournier, Tabet, & Cruzet, 1991; Srey, 2003). Crouzet et al. (1995) isolated and identified some aroma precursors of the apricot Rouge du Rousillon. They also found that the concentration of free VC was 1 mg/kg, while for the VC bound the detected concentration was 7.6 mg/kg. They also discovered that with the application of thermal treatments on fruits or juices of fruits the content of α-terpineol increases, in some cases the linalool content increases drastically from 90 to 4800 mg/kg and the concentration of terpene oxides also increase during these thermal treatments.

The released compounds of acid chemical hydrolysis can have different origins: this can be the result of reactions of polyalcohols between acid generating aliphatic alcohols, or result from the hydrolysis of glycosidic precursors like of those derived aromatically, or come from the carotene derivatives like it was the case for β-ionone (Guillot et al., 2006).

The enzymatically hydrolyzed extracts are characterized by the presence of derived carotenes and a higher quantity of aliphatic alcohols and derived aromatic compounds.

The aim of this work is to characterize different varieties of apricot on their quality but also on their aromatic potential in order to give recommendations onto their use fresh or transformed. Various methods were also compared to determine the most effective method but also verify if some are complementary.

2. Materials and methods

2.1. Plant material

Eight different varieties of apricot (Bergeron, Orangered, Hybride Blanc, Moniqui, Double rouge, Iranien, A4025 and Goldrich) were gathered in the National Institute of the Agronomic Investigation of Avignon and Melgueil, France (Institut National de la Recherche Agronomique, INRA). These varieties were chosen for their typical aroma and their different maturity period (Guichard & Souty, 1988; Guillot et al., 2006). Fifty fruits from each variety were harvested in a state of consumption maturity in 2002. Once in the laboratory, they were washed using distilled water, left to dry, deboned and turned into cubes (1–2 cm of thickness). They were quickly introduced in polyethylene bags impermeable to gases (1 kg for packing), kept frozen and stored for a few weeks at −20 °C before analysis. Preliminary studies using HS-SPME showed that differences between fresh and frozen fruits after six months storage were not significant; no differences were observed for A4025 and Bergeron (full season varieties). A reduced content (5%) of VC was observed for Hybride Blanc, Moniqui, Double rouge and Goldrich varieties and a reduced content (20%) of VC was observed for Iranien and Orangered the most precocious varieties. This indicates the reduction in VC was due not to the storage method but to the different apricot varieties.

2.2. Preparation of apricot saturated juice

Frozen apricot (300 g) was homogenized together with 150 mL of water UP (ultra pure) and 200 g of $(NH_4)_2SO_4$ in order to inhibit enzymatic reactions and proteins precipitation. The mixture was centrifuged at 10 000*g* during 30 min at 4 °C, and the saturated juice (supernatant) was recovered and stored at −20 °C.

2.3. Clarification of the saturated juice

Saturated juice (210 mL) was defrosted in a bath of water at room temperature (15–20 °C) and treated as Boulanger (1999): liquefied using a mixture of cellulose (5 g/L), pectinase (2 g/L) PVP (0.2 g/L) at 25 °C for 90 min, and

centrifuged (30 min, 10 000*g*) at 4 °C. The clear supernatant (saturated juice clarified) was used in the SPE.

2.4. Solid phase extraction (SPE)

The C18 column (Varian®, Walnut, CA, USA) was activated passing through 25 mL of CH_3OH and later 25 mL of water UP. Clarified saturated juice (50 mL) were mixed with 48 μg of 4-nonanol as internal standard (IS) (Aubert, Günata, Ambid, & Baumes, 2003) and filtrated through the column C18, at flow rate of 1.5 mL/min, the free aroma compounds (free fraction) were adsorbed in the column solid phase. The column was then washed with 30 mL of water UP to elute the polar components and the free fraction was eluted with 30 mL of CH_2Cl_2. Finally this fraction was conduced to the microdistillation process. The glycosidic fraction was eluted with 30 mL of CH_3OH and used immediately for enzymatic hydrolysis (see corresponding chapter).

2.5. Liquid–liquid extraction (LLE)

In a cold bath, 50 mL of saturated juice was blended with 30 mL of CH_2Cl_2 in order to extract the free volatile fraction or liberated during the hydrolysis and 48 μg of 4-nonanol as IS. The mixture was stirred during 30 min on a gaseous nitrogen saturated atmosphere. Later, the mixture was centrifuged at 10 000*g* at 4°C during 15 min (this extraction was done twice). Watery phase was removed and the organic phase (CH_2Cl_2 + volatile compounds) was treated by microdistillation process.

2.6. Simultaneous distillation extraction (SDE)

Frozen apricot (100 g) was mixed with 200 mL of phosphate buffer (pH 8), 48 μg of 4-nonanol as IS and 0.2 mL of silicone oil Rhodorsil (Prolabo) as anti-foaming agent (Bhattacharjee, Ranganathan, Singhal, & Kulkani, 2003), during 4 min. The final pH was on a 7 ± 0.2 range.

The flask with the sample was assembled to the Likens–Nickerson apparatus and warmed at 100–120 °C range, until boiling, to evaporate the sample. Simultaneously in other section of the apparatus a small flask was assembled, with 30 mL of CH_2Cl_2, this was heated to 45 °C (boiling point), in order to extract the free aromatic fraction with steam. The heating of the sample stayed 2 h. The solvent was recovered and stored at −20 °C until their use in the micro distillation process.

2.7. Preparation of the sample (pH 7) for SDE

Frozen apricot (100 g) was mixed with 200 mL of phosphate buffer (pH 8), 48 μg of 4-nonanol and 0.2 mL of silicone oil Rhodorsil (Prolabo) as anti-foaming agent, during 4 min in a cold bath. The final pH was on a 7 ± 0.2 range to avoid the chemical hydrolysis of the glycosidic compounds. The mixture was transferred to 1 L ball bottom flask.

2.8. Preparation of the sample (pH 3) for SDE

Frozen apricot (100 g) was mixed with 200 mL of water UP, 48 μg 4-nonanol and 0.2 mL of silicone oil Rhodorsil (Prolabo) as anti-foaming agent during 4 min. The final pH should be in the 3 ± 0.2 range to ensure the chemical hydrolysis of the glycosidic compounds. The mixture was transferred to a 1 L ball bottom flask.

The aroma potential (AP) was calculated using the difference between the sums of the concentration of all extracted volatile compounds (VC concentration) at pH 3 and pH 7 (Eq. (1)).

$$\mathrm{AP} = \text{VC concentration pH } 3 - \text{VC concentration pH } 7 \quad (1)$$

2.9. Headspace solid phase microextraction (HS-SPME)

A puree was prepared by mixing 50 g of frozen apricot with 50 mL of water UP, in a cold bath. Five gram of this puree was placed in a 20 mL vial and 5 mL of a saturated solution of NaCl was added. The vial was sealed tightly and incubated at 40 °C during 1 h. The needle of the syringe SPME was then inserted and the fiber (Carboxen/PDMS de 65 μm, Supelco, Bellefonte, PA) was exposed in the head space inside the vial during 20 min. Desorption was finally made by exposing the fiber during 4 min in the injection port. These SPME conditions were optimized in a previous work (Guillot et al., 2006).

2.10. Enzymatic hydrolysis

Glycosidic extracts (30 mL, obtained from 50 mL of clarified juice) was concentrated to dryness in vacuum to 1 mL under nitrogen stream, then redisolved in 0.3 mL of 0.2 M citrate–phosphate buffer (pH 5) and extracted five times using CH_2Cl_2. The enzymatic preparation of AR-2000® (Gist-Brocades, Seclin, France) was made at 40 mg/mL in 0.2 M citrate–phosphate buffer (pH 5) and 0.3 mL was added to the residue. The mixtures were incubated at 40 °C for 16 h. After cooling at room temperature, 48 μg 4-nonanol was added as an IS and the mixtures extracted five times with 1 mL CH_2Cl_2. This aglycon extract was concentrated by micro distillation process.

AR-2000 composition: β-apiosidase (564.6 nkat/g), xylosidase (1760 nkat/g), α-rhamnosidase (236.2 nkat/g), α-arabinofuranosydase (13 500 nkat/g), α-arabinopyranosidase (576 nkat/g), β-D-galactopyranosidase (4444 nkat/g), and β-D-glucopyranosidase (4380 nkat/g).

2.11. Concentration using reflux (microdistillation)

The microdistillation process is the final step, commonly used in the extraction techniques with solvents here mentioned. The organic phase (CH_2Cl_2 + volatile components) coming from any of the methods (LLE, SDE and C18) was

concentrated by the following way: the organic phase was dehydrated with Na_2SO_4 and filtrated through glass fiber. The filtrate was then collected in a 250 mL flask of conical bottom. The sample filtrated was distilled in a Vigreux column by heating the flask of conical bottom in a bath at 45 °C to concentrate the volume of the sample approximately to 0.5 mL. The concentrated extract was stored at −20 °C in a 2 mL vial, until analysis in GC–FID.

2.12. GC–FID conditions

A Varian 3300 (Walnut Creek, CA, USA) chromatograph equipped with split/splitless injector and flame ionization detector (FID) was used for all GC analysis. A DB-WAX fused silica capillary column (J& W Scientific, Folsom, CA, USA) was employed (30 m × 0.25 mm i.d., film thickness, 0.25 μm). The column oven temperature was increased from 40 to 200 °C at 3 °C/min, then from 200 °C to 250 °C at 5 °C/min and maintained for 5 min at this final temperature. Hydrogen at 1.5 mL/min was used as carrier gas. The injector temperature was maintained at 250 °C and the detector temperature was 300 °C.

2.13. GC–MS conditions

Gas chromatograph Saturn 2200 (Walnut Creek, CA, USA) GC-MS was used, it was constituted by GC Varian 3800, provided of an injector split/splitless and a mass spectrum detector series 2000 that captures electrons to identify the molecules by electronic impact. The same column and temperature program as described above was used and helium at 1.5 mL/min was used as the carrier gas. The transfer line was 250 °C. Electron impact mass spectra was scanned at 70 eV in the m/z range 60–600 mass units and then compared with those present in commercial libraries (NIST/EPA/MSDC 49 K Mass Spectral Database, Hewlett–Packard Co., Palo Alto, CA USA and Registry of Mass Spectral Data with Structures, Wiley 6.1, NY, USA).

2.14. Data treatment

An analysis of variance (ANOVA) was performed on the data using the statistical design 8 × 4: 8 apricot varieties and 4 extraction techniques. The Tukey method was used in order to compare the averages. The statistical analysis was performed using SAS software (Statistical Analysis System 6.12 for windows).

3. Results and discussion

3.1. Free volatile fraction

The concentration of volatile compounds was determined in milligrams by kilogram of pulp for all techniques, considering the sum of the total area of all the compounds detected by GC–FID, those constitute all the free volatile compounds (VC) including aroma compounds (AC).

Fig. 1 shows the mean concentrations of VC extracted from the 8 apricot varieties. The concentration of VC was different in all the varieties and also according to the used extraction techniques. LLE and especially SPE gave the most and the highest VC concentrations, over and above other techniques. Such observations were made by Srey (2003) who concluded that in extractions performed with an organic solvent (LLE and SPE) a higher quantity of VC was obtained. For all extraction methods, the variation coefficients were always less than 20%, however SPE and SPME showed the higher values because solid phases took part in the extraction, producing in this manner variations in amounts extracted.

The total concentration of VC (mg/kg) from varieties was compared by analysis of variance (ANOVA) of a statistical design 8 × 4, the results showed a significant effect ($p < 0.01$) either in the variety and the extraction technique (Table 1). In the complete design (8 × 4), the concentration of VC in the 8 varieties is significantly different ($p = 0.05$). The extraction by SPE on C18 allows for the recovery of a higher concentration of VC, however, this parameter was not enough to differentiate all the varieties but different

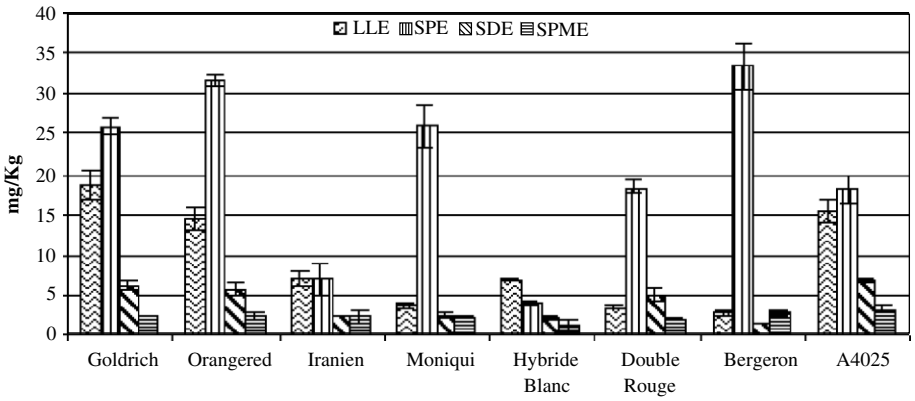

Fig. 1. Comparison of four extraction techniques of VC from the eight apricot varieties ($n_i = 3$, n_i = variety).

groups were observed. For the varieties Goldrich, Orangered and A4025 a high VC concentration was obtained by all the methods. On the other hand, Iranien and Hybride Blanc were varieties that expressed the lower VC contents by all the methods used. For Bergeron, Moniqui and Double Rouge, only the SPE gave high values of VC not confirmed by the others methods. These various groups were not made according to the maturity period because Orangered, Iranien and Double Rouge were precocious varieties; Goldrich was a half season variety; Moniqui, Hybride Blanc and A4025 were full season varieties; and Bergeron was a late variety.

Table 2 shows the aroma compounds (AC) identified in the varieties according to the extraction method used. The AC characteristics of apricot fruit found in scarce references on apricot volatiles are marked in italics (Guillot et al., 2006; Takeoka et al., 1990).

Table 1
Tukey means comparison of the VC concentration

T	Technique of extraction	Concentration (mg/kg)	T	Apricot varieties	Concentration (mg/kg)
A	SPE	18.84	A	Orangered	13.54
B	LLE	10.00	A	Goldrich	13.27
C	SDE	4.55	B	A4025	10.91
D	SPME	2.31	B	Bergeron	10.11
			C	Moniqui	8.61
			C	Double rouge	7.23
			D	Iranien	4.74
			D	Hybride blanc	3.58

T = Tukey grouping, means with the same letter (A, B, C, D) are not significantly different at $p = 0.05$, $n_i = 3$ (n_i = variety).

Linalool, α-terpineol, β-ionone and γ-decalactone were the common compounds extracted by the 4 methods in all the varieties. Lactones such as γ-decalactone were involved in the typical, basic apricot flavour, whereas compounds like terpene alcohols as linalool and α-terpineol, ketones as β-ionone and in some cases benzaldehyde were described as contributors of the flower and fruity notes of different apricot cultivars (Takeoka et al., 1990). Benzaldehyde was extracted by 3 methods, SPE, LLE and SDE, but not in all varieties by SPME.

LLE in spite of high content of VC does not give a lot of aroma compounds but most of them are major AC found in apricot as E-hexen-2-al, Benzaldehyde, Linalool, α-terpineol, β-ionone, γ-decalactone. The concentration step of this method could induce loss of AC.

The SPE on C18 was the best technique for recovery a higher concentration of VC, but most of them were not identified as AC according to the reduced number of compounds found.

SPME has been used for analysis of several flavour compounds more particularly in fruits (Beaulieu & Grimm, 2001; Guillot et al., 2006; Riu-Aumatel, Castellari, Lopez-Tamames, Galassi, & Buxaderas, 2004; Song, Fan, & Beaudry, 1998). The SPME was the technique extracting a smaller quantity of VC (Fig. 1), however this technique extracted a major number of AC especially esters, aldehydes and alcohols that were not extracted by any of the other techniques. We found in these varieties the 9 common volatile compounds identified in a previous study: ethyl acetate, hexyl acetate and β-cyclocitral with characteristic fruity notes; 6-methyl-5-hepten-2-one, linalool, and b-ionone with characteristic floral notes; limonene with

Table 2
AC identified in 8 apricot varieties by 4 extraction techniques

SPE	LLE	SDE	SPME
Methyl cyclopentane	*E-hexen-2-al*	Pyrazine	*Ethyl acetate*
Cis-linalool oxide	*Benzaldehyde*	*6-Methyl-5-hepten-2-one*	Butanol
Acetic acid	*Linalool*	Furfural	β-Pinene
Linalool oxide	1,3-Dimethylcyclohexanol	*Benzaldehyde*	*Hexanal*
Benzaldehyde	Cyclohexylisothiocyanate	*Linalool*	*Limonene*
Linalool	*α-Terpineol*	Pyridine	*E-hexen-2-al*
2,6-Dimethylcyclohexanol	*β-Ionone*	1-3-Dimethylcyclohexanol	*Hexyl acetate*
α-Terpineol	γ-Decalactone	β-Cyclocitral	Octanol
Epoxilinalool		*3,7-Dimethyl-1,6-octadiene*	3-Hexen-1-ol
Cyclohexanone		*Phenylacetaldehyde*	*6-Methyl-5-hepten-2-one*
Geraniol		Cyclohexylisothiocyanate	*Nonanal*
2,6-Dimethyl-7-octen-2,6-diol		*α-Terpineol*	*2-Ethyl-1-hexanol*
Isopropylmyristate		2-Ethylaniline	*Linalool*
Phtalate		*Benzyl alcohol*	2-4-Dimethylcyclohexanol
8-Hydroxilinalool		2-Butyl-1-octanol	*β-Cyclocitral*
5-Hydroxilinalool		*Nerol*	*α-Terpineol*
		Geranylacetone	Hexanoic acid
		β-Ionone	*Geranylacetone*
		γ-Decalactone	*p*-Cresol
		4-Vinyguaîacol	*β-Ionone*
		Farnesylacetone	*γ-Decalactone*
			Diethylphtalate

$n_i = 3$ (n_i = variety).

its citrus note; (E)-hexen-2-al with its grassy note and γ-decalactone with the typical peach and apricot jam note (Guillot et al., 2006). The menthone was only found in the present study in Goldrich and Orangered, the richest varieties in VC. SPE and SPME are selective methods, the very long procedure on SPE and C18 extraction could result in a low quantity of AC. In the other hand, SPME is a rapid method and the sample practically is not exposed to the atmosphere.

SDE gave a lot of AC according to the low content of VC extracted, like SPME but in SDE compounds resulting from thermal treatment like furfural, pyrazine and 4-vinyguaïacol, were also found. These compounds are frequently found in roasted food like coffee (Yeretzian, Jordan, & Badoud, 2002). β-Cyclocitral was known as resulting of thermal, photo oxygenation or enzymatic degradation of β-carotene the main carotenoid pigment found in apricot (Demole & Berthet, 1972; Drawert, Schreier, Bhiwapurkar, & Heindze, 1981; Gloria, Grulke, & Gray, 1993), whereas 6-methyl-5-hepten-2-one was described as resulting of the degradation of lycopene (Drawert et al., 1981; Waché, Bosset-De Ratuld, & Belin, 2002). Both compounds were found in apricot volatile fraction obtained by SDE but also by SPME like it was observed in a previous work (Guillot et al., 2006). According to the very different extraction methods, these compounds probably resulted from enzymatic or photochemical reactions occurring during the maturation process of apricots.

3.2. Bounded fraction: aroma potential

The total volatile compounds obtained by SDE at pH 7, the total VC+ the volatile compounds liberated by acid hydrolysis at pH 3, and the difference between the two contents qualified of aroma potential (AP) are presented in Fig. 2. In most of the cases the AP is bigger than the concentration of free VC but not for the varieties Goldrich and Double rouge. The Goldrich variety is the one with a higher concentration of VC, and its AP developed by sour hydrolysis is the smallest of all the varieties. The reason for such behavior could be its natural acidity, in state of consumption maturity its acid content is of 20.06 mEq/100 g of fruit, higher than the other varieties. It is probably that a hydrolysis is occurring at the normal pH of the fruit, reducing the hydrolysis rate in the SDE at sour pH.

In accordance with Srey (2003) and Guillot et al. (2006), the acid hydrolysis led to the release of numerous compounds especially terpenes and terpene oxides, aldehydes

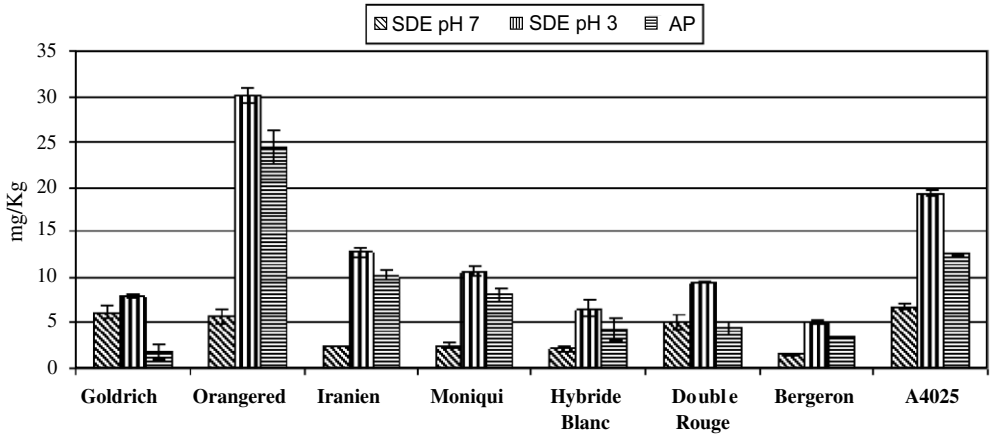

Fig. 2. Aroma potential developed by acid hydrolysis of the aroma precursors ($n_i = 3$, n_i = variety).

Table 3
AC released in the 8 apricot varieties after enzymatic or chemical hydrolysis of precursors

	Enzymatic hydrolysis	Chemical hydrolysis
Terpenes and Terpene alcohols	Linalool, α-terpineol, geraniol, eugenol, linalool oxides	Limonene, γ-terpinene, Linalool, α-terpineol, γ-terpineol, 4-terpinol, nerol, geraniol, linalool oxides
Benzene derivatives	Benzyl alcohol, 2-phenylethanol, benzaldehyde	Benzyl alcohol, 2-phenylethanol, benzaldehyde
Alcohols	Hexanol, 6-methyl-5-hepten-2ol 2,6-Dimethyl-7-octen-2,6-diol, 2,6-dimethyl 1,7-octendiene-3,6-diol	2,6-dimethyl-5-heptenol, 2-methyl-3-octanol
Ketones	β-Ionone, 6-metyl-5-hepten-2-one 3-Hydroxy-7,8-dihydro-β-ionone (BIN3H) 3-Hhydroxy-5,6-epoxy-β-ionone (BIN3E) 3-hydroxy-β-ionone	α-Ionone, β-ionone
Aldehydes		Hexenal, E-hexen-2-al, furfural, β-cyclocitral
Lactones		*y*-decalactone, *y*-dodecalactone

$n_i = 3$ (n_i = variety).

and lactones while enzymatic hydrolysis generated more alcohols and ketones (Table 3). Linalool, α-terpineol, benzyl alcohol, 2-phenyethanol, and β-ionone are the major compounds released by both methods. The main glycosides found in apricot are indeed glycosides of terpene alcohols and glycosides of aromatic alcohols (Chassagne & Crouzet, 1995; Salles et al., 1991). Numerous C13-norisoprenoid compounds and derivatives were also found as β-ionone, BIN3H, BIN3H and 3-hydroxy-β-ionone (Krammer et al., 1991).

Fig. 3 presents the aroma potential developed by both hydrolysis methods. The SPE on C18 was more specific due to the fact that the separation of the precursors selectively before enzymatic hydrolysis was done.

The varieties Goldrich and Bergeron, which developed a poor PA by the sour chemical hydrolysis, were two of the four varieties that developed a bigger PA for the enzymatic hydrolysis (Fig. 3). The PA developed by enzymatic hydrolysis is bigger than the ones developed by chemical hydrolysis, except for Iranien, A4025 and especially Orangered which developed grassy and fruity notes after chemical hydrolysis by liberation of aldehyde and lactone as it was observed in a previous study (Guillot et al., 2006).

Due to these results, it is possible to conclude that the aromatic potential could suggest the process type to which can be subjected the fruit. The fruits that developed a bigger PA on sour hydrolysis could be used in the production of purees, marmalades, juices, etc. such varieties are Orangered, Iranien and A4025, because this type of processes involves thermal treatments that would favor sour chemical hydrolysis of the aroma precursors, enriching to the aroma of the final product. Likewise, if some varieties develop a higher PA by enzymatic hydrolysis they could be used in the liquors manufactured and other fermented foods, because the enzymatic action in the fermentation process derived from microorganisms presence or for an enzyme added to the process with this objective in particular to hydrolyze the aroma precursors. The appropriate varieties for such processes are Goldrich, Bergeron and Double rouge. However it is necessary to realize additional experimental work from the qualitative point of view to verify the real impact of these released compounds on the aroma taking into account olfactometric criterion, the aroma formulation could be changed enough to deeply modify the global note.

Statistically the PA of the apricot was compared with an ANOVA (analysis of variance) and a mean test of an experimental design 8 × 2 (Table 4), 8 varieties of apricot and 2 hydrolysis methods. The results show a significant effect of the hydrolysis method and of the apricot varieties

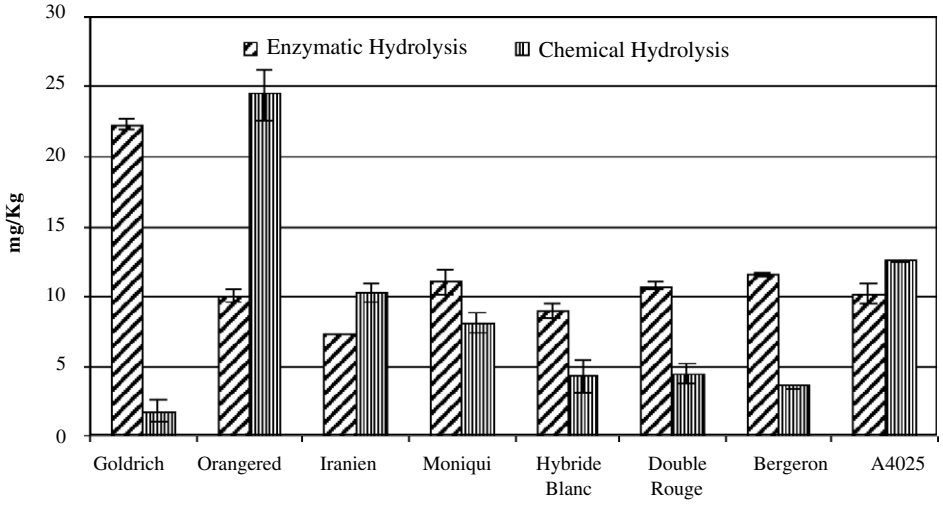

Fig. 3. Aroma potential developed by two hydrolysis methods of the aroma ($n_i = 3$, n_i = variety).

Table 4
Statistical analysis of the AP developed for two hydrolysis methods

T	Hydrolysis method	Concentration (mg/kg)	T	Apricot varieties	Concentration (mg/kg)
A	Enzymatic	12.63	A	Orangered	17.23
B	Acid	7.88	B	Goldrich	12.06
			BC	A4025	11.36
			DC	Moniqui	9.55
			DE	Iranien	8.75
			FE	Double Rouge	7.58
			FE	Bergeron	7.53
			F	Hybride Blanc	6.66

T = Tukey grouping means with the same letter (A, B, C, D, E, F) are not significantly different at $p = 0.01$, $n_i = 3$ (n_i = variety).

($p < 0.01$). As previously mentioned, the enzymatic hydrolysis produces a higher PA.

The PA decreased in the following order of varieties: Orangered, Goldrich, A4025, Moniqui, Iranien, Double Rouge, Bergeron, Hybride Blanc. In general, the differences among the varieties are not significatively marked according to their aromatic potential.

4. Conclusions

The concentration of volatile compounds depends on the variety and the extraction technique used. The higher concentration was obtained for the Orangered variety and for solid phase extraction in reverse phase.

The aroma of a food is not related to the total concentration of volatile compounds, but to the aromatic compounds characteristics of the fruit (impact compound) that are in that volatile fraction.

The solid phase micro extraction was the technique that allowed for the highest number of aromatic compounds which determined the characteristic aroma of the apricot fruit.

Any extraction technique produced a complete analysis of the sample, but they complemented each other.

The concentration of volatile compounds glycosidically-bounded depends also on the apricot variety and the extraction technique used. The Orangered variety developed the higher PA especially during the enzymatic hydrolysis after SPE on C18.

The glycosidic precursors are an important reservation of the aroma, since the aroma potential developed is generally higher to the free volatile fraction.

Consumption of fresh apricots is recommended for varieties rich in free aromatic compounds, such as Orangered and Goldrich and for varieties that are not able to develop a higher aromatic potential, as Hybride blanc.

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