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Indigenous *Saccharomyces cerevisiae* strains and their influence on the quality of Cataratto, Inzolia and Grillo white wines

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ABSTRACT

The present paper deals with three new strains of *Saccharomyces cerevisiae*, isolated in old wineries of Sicily, which were microbiologically and molecularly characterized and tested for their ability to produce white wines. Examined in terms of their growth pattern, fermentation vigour, sulphite tolerance, fermentative power, spore formation, and production of acetic acid, hydrogen sulphide and phenolic off-flavours, the strains were utilized as starters in experimental fermentations of musts obtained from the cultivars Inzolia, Grillo and Catarratto. Further, the three musts were also fermented using two commercial *S. cerevisiae* strains. The quality of the wines produced was confirmed by their principal oenochemical parameters, by sensory analysis and qualitative and quantitative determination of the volatile aroma constituents. All the data were statistically elaborated. Interestingly, the new selected yeasts were able to increase the pear notes (Z)-ethyl-4-decenoate, (E)-ethyl-3-decenoate, and (Z)-ethyl-3-decenoate which are fundamental for the aroma of these Sicilian wines. From our results, the new yeast strains were found to produce white wines of a quality which was not inferior to those obtainable with the best commercial strains selected in other geographical areas, but also with a distinctive aromatic profile.

1. Introduction

In winemaking, the use of a yeast starter culture ensures an adequate control of the alcoholic must fermentation. Today a wide variety of dried *Saccharomyces cerevisiae* yeast strains are commercially available and able to prevail over the native yeasts in the must and avoid the risks associated with the development of species potentially detrimental to the wine quality. However, in those regions which are well-known for typical wines, it would preferable to use a starter of indigenous yeasts of the same area (Moreno, Millàn, Ortega, & Medina, 1991); in fact, each strain of *S. cerevisiae* is able to produce different types and quantities of secondary compounds which are determinant on the desirable aromatic characteristics of a wine (Pretorius, 2000). Further, the selected yeast strains should produce very low quantities of unpleasant compounds which could compromise the quality of the bouquet. In fact, in the case of white wines, both *Saccharomyces* and non-*Saccharomyces* yeasts have been found to produce undesired phenolic compounds (Chatonnet, Dubourdieu, Boidron, & Pons, 1992). The volatile phenolic compounds, such as 4-vinyl guaiacol or 4-vinyl phenol, are produced through the decarboxylation of ferulic acid and p-cumaric acid, respectively, and the subsequent reduction of these compounds leads to the formation of 4-ethyl guaiacol and 4-ethyl phenol. These volatile phenols have a distinctive aroma judged to be "smoky", "pharmaceutical" or "leathery" even if present in small quantities in the grapes. When present at high levels in wine, they result in a defect called *phenolic off-flavour* (POF) (Thurston & Tubb, 1981).

The Regional Institute of Vine and Wine (IRVV) (Palermo, Italy) has isolated more than 900 *S. cerevisiae* yeasts from spontaneous fermenting musts, in order to study and preserve the biodiversity of these indigenous populations and also to identify promising yeast strains for use in winemaking. This collection of yeasts is characterized by high genetic variability and the identification of some characteristic phenotypes,

Abbreviations: POF, phenolic off flavour; IRVV, Istituto Regionale della Vite e del Vino; PCR, polymerase chain reaction; DIPROVAL, Dipartimento di Protezione e Valorizzazione Agroalimentare; mtDNA-RFLP, mitochondrial DNA-restriction fragments length polymorphisms; YPD, yeast peptone dextrose; TBE, tris borate EDTA; EDTA, ethylene diamine tetraacetic acid; EEC, Economic European Community; WL, Wallerstein Laboratory nutrient agar; HS-SPME–GC–MS, head space-solid phase micro extraction-gas chromatography–mass spectrometry; DVB/CAR/PDMS, DiVinylBenzene/Carboxen/PolyDiMethylSiloxane; CP-Wax 52 CB, Chrompack Wax 52 Chemically Bonded; PCA, principal component analysis; ANOVA, analysis of variance; Bp, base pairs.

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fundamental in the oenological selection of yeasts, allowed the selection of 35 strains as being potentially excellent grape must ferments (Di Maio, Polizzotto, Di Gangi, Foresta, & Oliva, 2009). One of these strains has been marketed as active dried yeast since 2006 and has given excellent results in the production of wines from Nero d'Avola and other black grape varieties (Di Maio et al., 2006; Oliva et al., 2006).

The present paper describes the results of experimental white wine production using three strains of yeast from the IRVV collection, identified by codes A2-40, A3-2 and A4-9, distinguished by the positive values of some important oenological properties. The quality of the wines produced was confirmed by their principal oenochemical parameters, by sensory analysis and qualitative and quantitative determination of the volatile aroma constituents. The aim of the research was to evaluate the contribution of the selected yeast for enhancing the quality of white wines from autochthonous grapes: Grillo, Cataratto and Inzolia.

2. Materials and methods

2.1. Yeast strains

S. cerevisiae yeast strains A2-40, A3-2 and A4-9 belong to the oenological yeasts collection of the Regional Institute of Vine and Wine (IRVV) and were isolated in Sicily (Italy). Commercial *S. cerevisiae* strains VL1 (POF-) and EC1118, used as controls in fermentation trials, are produced by Laffort (France) and Lallemand (Canada), respectively. Commercial *S. cerevisiae* strains BA11, ICV-K1, ICV-D254 and RC212 are produced by Lallemand (Canada); *S. cerevisiae* strain L404 belongs to the DIPROVAL collection-University of Bologna (Italy) and is commercialized by Oliver-Ogar (Italy). *Hanseniaspora uvarum* 1-03 strain belongs to the oenological yeasts collection of the Regional Institute of Vine and Wine (IRVV). All the yeasts were maintained at 4 °C on Sabouraud Dextrose Agar (Oxoid, Hampshire, UK) medium slants enriched with 1% Yeast Extract (Oxoid, Hampshire, UK). The DNA of the three strains A2-40, A3-2 and A4-9 was extracted following the method described by Querol, Barrio, Huerta, and Ramon (1992) and then used for subsequent experiments as described by Granchi, Bosco, Messini, and Vincenzini (1999). PCR products were then digested with 3 units of the restriction endonuclease HaeIII (New England Biolabs, Hertfordshire, England). For all three strains, fragments of 320, 225, 180 and 145 base pairs were obtained, typical of the species *S. cerevisiae* and *Saccharomyces paradoxus.* To further distinguish between these two species, a *S. cerevisiae*-specific PCR was performed according to Sabaté, Guillamon, and Cano (2000). In both analyses the *S. cerevisiae* 6167 and *Saccharomyces bayanus* 11719 DIPROVAL (Bologna University) yeasts were used as control strains.

2.2. Determination of oenological characteristics of yeast strains

Fermentation vigour and sulphite tolerance were assayed following Caridi, Cufari, and Ramondino (2002) in white must, made from concentrated must. The DIPROVAL *S. cerevisiae* L404 strain was used as positive control, while non-inoculated models acted as negative control. Fermentation vigour and sulphite tolerance were determined as the weight loss caused by the liberation of CO_2 (g CO_2/100 mL) after 2 and 7 days incubation at 25 °C. The mean values of fermentation vigour shown by the L404 strain were 4.66 g/100 mL (after 2 days) and 10.92 g/100 mL (after 7 days), while sulphite tolerance was 4.58 g/100 mL (after 2 days) and 10.48 g/100 mL (after 7 days). The growth pattern of each strain was evaluated observing samples in fermentation of the different strains using a Zeiss Axioskope2 Plus Microscope (Carl Zeiss, Oberkochen, Germany). Following Regodón, Peréz, Valdés, De Miguel, and Ramìrez (1997), killer factor production was evaluated on medium 4.7 MB on a layer of the sensitive strain BA11 (Lallemand). The commercial strains ICV-K1 and EC1118 (Lallemand) were used as positive controls, and the strains ICV-D254 and RC212 (Lallemand) as negative controls. In order to evaluate spore-producing capacity, the different strains were cultivated at 30 °C for 7 days on acetate agar as described in Caridi et al. (2002). Cellular films for microscope examination were coloured according to Schaeffer and Fulton (1933). The spores, coloured blue, and vegetative cells, coloured red, were then examined using a Zeiss Axioskope2 Plus Microscope (Carl Zeiss, Oberkochen, Germany). Acetic acid production was evaluated on calcium carbonate agar (Caridi et al., 2002). The DIPROVAL *S. cerevisiae* L404 strain was used as negative control, while the strain *H. uvarum* 1-03 (from the IRVV collection) (Romancino, Di Maio, Muriella, & Oliva, 2008) was used as positive control. Hydrogen sulphide production was evaluated on BiGGY agar as described in Nickerson (1953). The β-glucosidase production was assayed following Strauss, Jolly, Lambrechts, and van Rensburg (2001). Production of phenolic off-flavour (POF), was assayed according to Shinohara, Kubodera, and Yanagida (2000) in white grape must (20 Brix, pH 3.2). A control yeast strain (Zymaflore VL1, Laffort) and reference samples, consisting of must without acids, were used in each experiment.

2.3. Fermentation

The experimental winemaking was performed during the 2006 vintage. Inzolia and Catarratto grapes came from a vineyard situated in Biesina county (Marsala, Italy), Grillo grapes from the island of Mothia (Marsala, Italy). Transported to the IRVV Experimental Winery in Marsala (Italy), the grapes were pressed and the musts obtained were sulphited (0.05 g/L), dosed with ascorbic acid (0.05 g/L) and pectolytic enzymes (0.02 g/L), static cold clarified at 8 °C for 24 h and then subjected to the oenochemical analysis listed in Table 1. Microbiological monitoring before and after clarification showed a lowering of the indigenous bioburden before inoculation with the cultures of the selected yeast strains. The single lot of clarified must was subdivided into 5 aliquots of 100 L, each of which was then inoculated at a ratio of 5% (v/v) (Zambonelli, Tini, & Castellari, 2000) with the liquid culture of one of the 5 yeast strains, the IRVV strains A2-40, A3-2 and A4-9 and the commercial strains Zymaflore VL1 (Laffort, Bordeaux Cedex, France) and EC1118 (Lallemand, Montréal, Canada). The pure cultures of the 5 *S. cerevisiae* strains were obtained by reproduction in must (20 Brix, pH 3.20) obtained by diluting concentrated must. Fermentation was performed at 17 to 19 °C. During fermentation, the quantity of sugars present was monitored through densitometric measurement of Babo degrees every day, together with temperature and microbiological controls. The end of fermentation was determined on the basis of the exhaustion of reducing sugars (<3 g/L). Fermentation lasted 14 days for Catarratto musts and between 16 and 22 days for those of Inzolia and Grillo. The musts were then racked and sulphur dioxide (0.04 g/L) was added: samples of the dregs at the bottom of the fermentation vessels were immediately cryo-preserved for subsequent molecular analyses to identify the yeasts present at the end of the fermentation process. Wine samples were collected from each vessel for subsequent oenochemical analyses. In December 2006, after a further racking and a final addition of sulphur dioxide (0.04 g/L), the wines were bottled.

Table 1
Oenological parameters for Grillo, Inzolia and Catarratto musts before yeast inoculation.

	Grillo	Inzolia	Catarratto
Brix	22.2	23.2	22.2
pH	3.30	3.48	3.29
Total acidity (g/L)	6.8	6.3	6.0
Yeast available nitrogen (mg/L)	133a[a]	144b	232c

[a] Different letters in the same row represent significant differences at $P<0.05$ by Duncan's multiple range test.

2.4. Microbiological controls

Each day, microbiological controls were performed according to Cavazza and Poznansky (1998). Further microbiological analyses on WL Nutrient Agar and Lysine Agar (Oxoid, Hampshire, UK) and on Tomato Juice Agar (Fluka, Sigma-Aldrich, St. Louis, Missouri) were performed after the bottling to ensure that microorganisms able to alter the bouquet of the wines had not developed.

2.5. Molecular analyses

The analysis of restriction fragments length polymorphisms of yeast mitochondrial DNA (mtDNA-RFLP) was performed on samples of the dregs collected from the bottom of each vessel after the first decanting. The protocol followed was that described by Querol et al. (1992), but the pre-cultures of the samples of dregs were prepared in YPD (yeast extract 10 g/L, peptone 20 g/L, glucose 20 g/L) with tetracycline (30 ppm) to inhibit the development of any bacteria present. The total yeast DNA was digested with restriction endonuclease RsaI (New England Biolabs, Hertfordshire, England), according to the supplier's instructions.

2.6. Oenochemical analyses of musts and wines

Alcoholic strength, pH, volatile acidity, total acidity, reducing sugars, total and free sulphur dioxide, extracts, total polyphenol content and chromatic characteristics of the wines were determined following the EEC Official Methods (EEC, 1990). Malic, lactic, succinic and citric acids, glycerol and acetaldehyde of the wines were determined using the appropriate enzymatic kits (Diffchamb, Mansfield, Nottinghamshire, UK and Boehringer Ingelheim, Ingelheim am Rhein, Germany) according to the supplier's instructions. Yeast available nitrogen was measured according to Gump, Zoeclein, and Fugelsang (2000).

2.7. Extraction and analysis of volatile compounds: HS-SPME–GC–MS

A 40-ml vial was filled with 20 mL of each sample. Extraction was performed by SPME using a DVB/CAR/PDMS fibre, of 50/30-μm film thickness (Supelco, Bellefonte, PA, USA) and analysed by GC/MS as previously reported (Verzera et al., 2008; Scacco et al., 2010).

2.8. Sensory analysis

Twenty-five judges were recruited from the students of the Department of Food Science and Technology, Catania University. Candidates were submitted to preliminary tests to determine their sensory performance on basic tastes and the aromas associated with wines. The sensory profiles (ISO, 2003a) of the wines obtained from Grillo, Inzolia, and Catarratto grapes were constructed using three selected panels (ISO, 1993) each of twelve judges trained over several sessions. The panels selected descriptive attributes regarding appearance, odour, taste and texture on the basis of the frequency (%) of the terms used by the judges in several sessions. Reference standards were available to define descriptors (Noble et al., 1987). The final set consisted of 10 descriptors for Grillo, 13 for Inzolia, and 13 for Catarratto. The different descriptors were quantified using a nine-point intensity scale (ISO, 2003b). The wines were tested in triplicate. All evaluations were made between 10.00 and 12.00 a.m. in individual booths (ISO, 2007). Fifty millilitres of each wine was served at 22 °C ± 1 °C (room temperature) in glasses (ISO, 1977) labelled with a 3-digit code and covered to prevent volatile loss. The order of presentation was randomized among judges and sessions. Water was provided for rinsing between wines. The data were collected on a direct registration system (FIZZ Biosystemes, Couternon France).

2.9. Statistical analysis

Sensory data were statistically analysed using FIZZ software. Both sensory and chemical data were submitted to analysis of variance (ANOVA) and PCA using the Statgraphic plus software (v5.1). Duncan's multiple-range test was applied to the chemical data to determine the presence of significant differences between the analysed samples; the model was statistically significant with a P value less than 0.05. The raw data was analysed directly, without any pre-processing (Souza et al., 2011).

3. Results

3.1. Selection of A2-40, A3-2 and A4-9 strains and their molecular analysis

In order to identify the yeast strains most suitable for the production of white wine, 35 strains of *Saccharomyces* in the IRVV collection which showed the best oenological characteristics (Di Maio et al., 2009) were assessed for their ability to produce unpleasant phenolic odours. The results of this assessment allowed the identification of three strains with reduced POF activity: in particular, three strains, coded A2-40, A3-2 and A4-9, were judged suitable for white wine fermentation. Table 2 reports their principle oenological properties.

Two different methodologies were used to confirm that the three strains belong to the species *S. cerevisiae*, previously determined applying microbiological methods (Di Maio et al., 2009). The first is based on amplification of the ITS regions of ribosomal DNA and subsequent digestion by HaeIII restriction endonuclease (Fig. 1) (Granchi et al., 1999) while the second amplifies a sequence of ribosomal DNA using species-specific primers (Fig. 2) (Sabaté et al., 2000).

3.2. Fermentations

The microbiological monitoring performed before and after clarification showed that the bioburden was reduced by 91% in the Inzolia must, by 71% in Grillo must and by 77% in Catarratto must, with values, relative to non-*Saccharomyces* yeasts, of 1.3×10^5, 5.5×10^4 and 3.8×10^5 cfu/mL in the corresponding clear musts. Daily microbiological monitoring for the count of *Saccharomyces* and non-*Saccharomyces* yeasts showed that, in Inzolia musts, the *Saccharomyces* strains were inoculated with values between 1 and 2×10^6 cfu/mL with an initial ratio of *Saccharomyces*/non-*Saccharomyces* between 7.6 and 15, which already exceeded 20 on the 2nd day of fermentation; the various strains of yeast reached

Table 2
Oenological properties of the three new strains of *S. cerevisiae*.

Oenological properties	A2-40	A3-2	A4-9
Growth pattern	dispersed cells	dispersed cells	dispersed cells
Fermentation vigour at 2 days (gCO_2/100 mL)	3.84a[a]	4.36b	4.04b
SO_2 tolerance at 2 days (gCO_2/100 mL)	3.52a	4.20b	3.96b
Fermentation vigour at 7 days (gCO_2/100 mL)	9.18	9.58	8.98
SO_2 tolerance at 7 days (gCO_2/100 mL)	9.20	9.64	9.40
Killer factor production	–	–	–
Spores production	+	+	+
Acetic acid production	Medium–low	Medium–low	Medium–low
H_2S production	Medium	Medium	Medium
β-glucosidase production	–	–	–
POF production	Low	Low	Low

[a] Different letters in the same row represent significant differences at $P<0.05$ by Duncan's multiple range test.

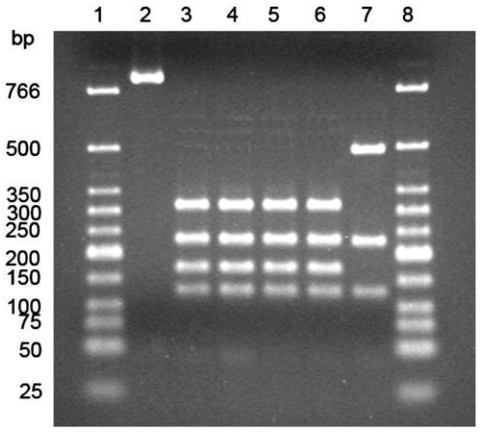

Fig. 1. HaeIII restriction patterns of ITS-region amplicons. Lanes 3–7: IRVV strains A2-40, A3-2 and A4-9 and DIPROVAL 6167 and 11719 digested amplicons. Lane 2: integral A2-40 ITS amplicon. Lanes 1 and 8: low molecular weight DNA ladder.

maximum cellular concentration between the 4th and 9th day of fermentation, with values between 46 and 73×10^6 cfu/mL. In Grillo musts, *Saccharomyces* strains were inoculated with values between 1.2 and 3.2×10^6 cfu/mL with an initial ratio of *Saccharomyces*/non-*Saccharomyces* between 21 and 58, which already exceeded the value of 100 on the 2nd day of fermentation; the various yeast strains reached a maximum cellular concentration between the 4th and 12th day of fermentation, with values between 70 and 85×10^6 cfu/mL. In Catarratto musts, *Saccharomyces* strains were inoculated with values between 0.6 and 1.8×10^6 cfu/mL with an initial *Saccharomyces*/non-*Saccharomyces* ratio between 1.7 and 4.6, which exceeded the value of 20 in all the trials within 2 days from inoculation; the various yeast strains reached their maximum cellular concentration between the 4th and 9th day, with values between 73 and 140×10^6 cfu/mL. In all fermentations, therefore, there was a rapid growth of *Saccharomyces* yeasts to the detriment of the other yeast species present: Fig. 3a shows the trend in the case of Catarratto must inoculated with strain A3-2. The lag phase occurring between inoculation of the selected yeasts and their prevalence in the must, always brief in all fermentations, further reduced the risks associated with a possible growth of wild non-*Saccharomyces* yeasts, which instead underwent a quite rapid decline. Due to the reduced persistence of these indigenous yeasts and to the starter rapidly reaching numerical superiority in all fermentations, any contribution from non-*Saccharomyces* populations to the final quality of the wine may be considered minimal. Fermentation lasted between 14 and 18 days, except in Grillo and Inzolia musts inoculated with the A2-40 strain which extended to 22 days, a length of

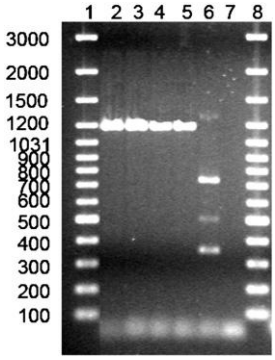

Fig. 2. *S. cerevisiae*-specific PCR. Lanes 2–6: IRVV strains A2-40, A3-2 and A4-9, DIPROVAL 6167 and 11719 and free-DNA PCR product. Lanes 1 and 8: GeneRuler™ 100 bp DNA Ladder Plus.

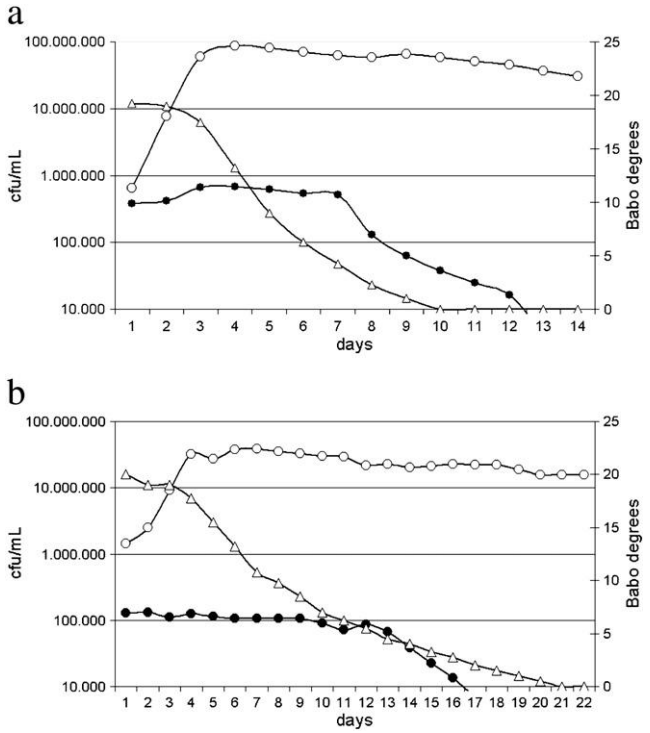

Fig. 3. Growth curves of *Saccharomyces* and non-*Saccharomyces* yeasts in Catarratto must inoculated with the strain A3-2 (a) and Inzolia must inoculated with the strain A2-40 (b). ○ = *Saccharomyces*; ● = non-*Saccharomyces*; △ = Babo degree. The curves of the other fermentations (data not shown) are analogous to those reported in this figure.

time which increases the costs of using this strain in industrial production due to the greater energy consumption in maintaining the low fermentation temperatures. Fig. 3b shows the trend in the case of Inzolia inoculated with the strain A2-40. Molecular monitoring, by analyses of mtDNA-RFLP, performed on the dregs collected at racking, showed that the various strains found at the end of fermentation were those which had initially been inoculated (Fig. 4).

3.3. Oenochemical parameters

The main oenochemical parameters, indispensable information for an assessment of the qualitative wine standard in relation to the inoculated strain, are reported in Table 3: the values were generally comparable for wines obtained from the same initial must. In particular, the strains left low levels of residual sugars and ethanol content which were similar in all wines obtained from the same variety of grape. The values of glycerol produced by the IRVV and commercial yeasts ranged between 5.5 and 9.1 g/L: at these concentrations, glycerol contributes to the viscosity and softness of the wine, with a positive effect on its taste. The total acidity content was analogous in all wines (5.6 to 6.6 g/L) and the level of volatile acidity, with the principal contribution of the acetic acid produced by yeast during fermentation, was between 0.20 and 0.63 g/L. The differences in the malic and succinic acid content of the wines produced from the same initial must did not exceed 0.3 g/L, while the citric acid content did not differ by more than 0.1 g/L. Acetaldehyde values were between 19 and 46 mg/L and, at these concentrations, do not negatively influence the sensory profile of the wine but rather give it a pleasant fruity aroma (Vincenzini, Romano, & Farris, 2005). Differences in the total polyphenol content were not directly correlated to the different yeast strains employed, while the relative differences in intensity of colour were minimal.

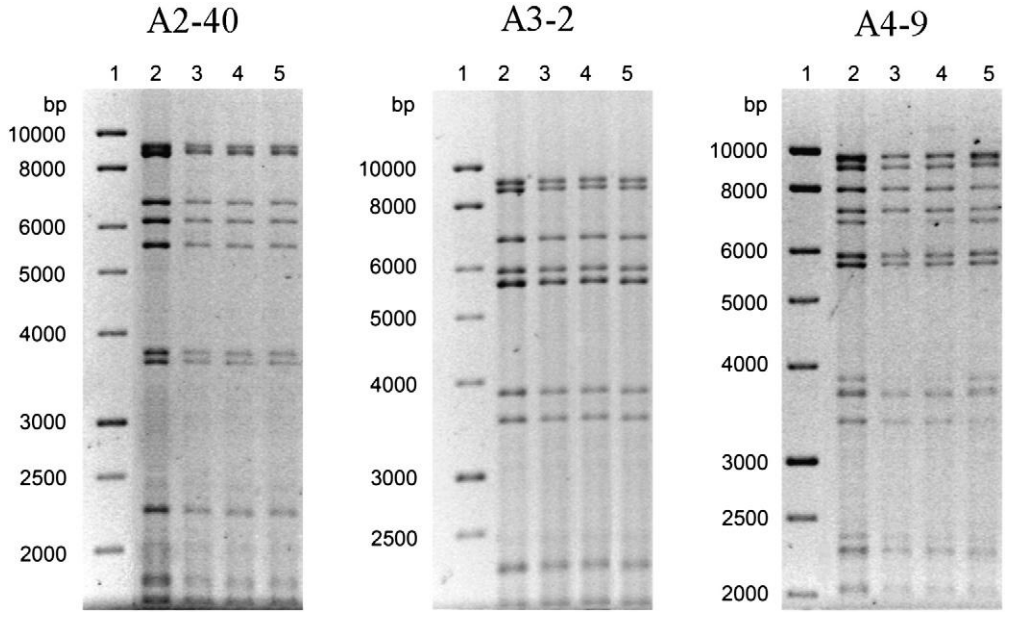

Fig. 4. Molecular checks performed at end of fermentations. Lanes 3–5: mtDNA-RFLP from Inzolia, Grillo and Catarratto dregs of wines, inoculated with IRVV strains, compared to pure culture of the same strains (lanes 2). Lanes 1: 1 kb DNA ladder.

3.4. Aroma volatile compounds

As regards the volatile fraction of the different wine varieties, a large number of components (Table 4) were identified in each wine variety sample analysed; esters, fatty acids, alcohols, terpenes, and aromatic compounds. Ethyl esters of fatty acids and acetates of higher alcohols were the dominant esters in the wines analysed, with ethyl octanoate (banana, fruit, fat) and ethyl decanoate (fruity, oily, floral) the main compounds. Linear saturated fatty acids were identified with octanoic and decanoic as the main components. Among alcohols, isoamyl alcohol (fruity, winey) and β-phenylethyl alcohol (floral) prevailed; limonene (citrus) and (Z)-nerolidol (floral, green, citrus) were also identified. Although the compounds identified were the same, each wine showed a typical composition mainly due to a different ratio between the volatile aroma compounds and also a greater amount of esters in the Inzolia wine (Table 4). Within each variety, comparing the aroma volatile composition of the wines obtained using the commercial, A3-2, A4-9 and A2-40 yeast strains, significant differences were observed for most of the identified components; e.g. the yeast strain A2-40 behaved differently, producing the lowest amount of almost all the fermentation compounds, both for Inzolia, Grillo and Cataratto grapes; moreover, the lowest amounts of isoamyl alcohol and isoamyl acetate were found in wines from the newly isolated strains.

3.5. Sensory profile of the produced wines

Scores of the attributes of the sensory profiles for each sample are reported in Table 5. Grillo wine is described by one attribute referring to appearance (colour intensity), six to aroma (citrus, apple, floral, herbaceous/vegetative, exotic fruit and pungent) and two to taste (acid and bitter); Inzolia by two attributes referring to appearance (colour intensity and clearness), nine to aroma (fruity, citrus, tree fruits, apple, pear, exotic fruit, banana, dried fruit, floral, herbaceous/vegetative, and pungent) and two to taste (acid and bitter); Catarratto by two attributes referring to appearance (colour intensity and green reflexes), nine to aroma (citrus, tree fruits, apple, pear, banana, floral, herbaceous/vegetative, and pungent) and two to taste (acid and bitter). For each cultivar samples, no significant differences were found for most of the descriptors according to the

Table 3
Oenochemical parameters for Grillo, Inzolia and Catarratto wines.

	Grillo					Inzolia					Catarratto				
	VL1	EC1118	A2-40	A3-2	A4-9	VL1	EC1118	A2-40	A3-2	A4-9	VL1	EC1118	A2-40	A3-2	A4-9
Alcohol (% vol)	14.3	14.4	14.3	14.4	14.3	14.2	14.1	14.1	14.1	14.2	13.4	13.4	13.4	13.5	13.6
Total extract (g/L)	23.1	23.0	22.6	22.8	22.6	25.0	24.3	24.6	24.1	24.7	20.6	22.1	21.0	21.0	20.9
pH	3.24	3.23	3.18	3.24	3.24	3.55	3.50	3.61	3.52	3.57	3.46	3.50	3.50	3.48	3.53
Sugars (g/L)	2.6	2.5	2.3	1.7	1.9	2.1	2.2	2.3	2.4	2.6	1.1	1.1	1.2	1.1	1.3
Total SO_2 (mg/L)	139b	128b	98a	138b	136b	102	108	100	99	96	70	100	96	76	93
Free SO_2 (mg/L)	39b	32b	22a	27b	33b	24	21	25	18	20	26	30	31	30	37
Volatile acidity (g/L)	0.42a[a]	0.45a	0.63b	0.39a	0.31a	0.49b	0.25a	0.32a	0.23a	0.20a	0.36b	0.40b	0.36b	0.54c	0.30a
Total acidity (g/L)	5.9	5.7	6.4	6.0	5.9	5.8b	6.5a	5.7b	6.3a	5.6b	6.6	6.5	6.6	6.2	6.1
Malic acid (g/L)	0.6	0.7	0.7	0.8	0.6	0.9	1.0	0.9	1.0	0.7	1.2	1.3	1.2	1.3	1.2
Succinic acid (g/L)	0.6	0.7	0.8	1.0	0.8	0.6	0.5	0.4	0.6	0.6	0.5	0.4	0.5	0.4	0.4
Citric acid (g/L)	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.3	0.4	0.5	0.5	0.5	0.6	0.5
Glycerol (g/L)	5.5a	6.5c	5.5a	6.7c	6.0b	9.1c	8.1b	6.4a	5.9a	8.5b	6.4	7.2	5.9	6.6	6.3
Acetaldehyde (mg/L)	30c	32c	46c	37b	37b	25a	30b	25a	30b	31b	21b	27c	24b	13a	19b
Polyphenols (mg/L)	102a	106a	140b	102a	110a	516b	488a	504b	530c	504b	179b	205c	183b	155a	176b
Colour intensity	0.123	0.110	0.120	0.126	0.136	0.220	0.230	0.211	0.238	0.206	0.083	0.099	0.099	0.099	0.096

[a] Different letters in the same row represent significant differences at $P<0.05$ by Duncan's multiple range test within each cultivar.

Table 4

Compounds	LRI[#]	VL1	EC1118	A2-40	A3-2	A4-9
a. Volatiles[$] in the Inzolia wines by different strains						
Esters (μg/L)						
Ethyl butanoate	1036	3.25[a,*]	5.75[b]	2.91[a]	3.63[a]	4.41[a]
Ethyl 2-methylbutanoate	1051	0.11[b]	–[∞,a]	–[a]	0.18[b]	0.19[b]
Ethyl 3-methylbutanoate	1065	0.24[b]	0.17[b]	–[a]	0.32[b]	0.31[b]
Isoamyl acetate	1115	70.74[b]	85.25[b]	48.58[a]	52.80[a]	55.21[a]
Ethyl hexanoate	1226	118.00[a]	134.95[b]	110.15[a]	139.46[b]	133.48[b]
Hexyl acetate	1263	9.50[a]	11.02[b]	9.34[a]	9.94[a]	11.07[b]
Ethyl heptanoate	1326	0.50	0.38	0.40	0.70	0.32
Methyl octanoate	1394	1.26[b]	1.50[b]	0.99[a]	1.38[b]	1.49[b]
Ethyl octanoate	1438	2206.44[b]	2325.67[b]	2015.00[a]	2399.80[b]	2474.20[b]
(Z)-ethyl-3-octenoate	1481	1.34[b]	0.42[a]	0.88[a]	2.02[c]	1.07[b]
Propyl octanoate	1517	0.79[a]	1.13[b]	0.64[a]	0.78[a]	0.92[b]
Ethyl nonanoate	1530	1.61	1.64	1.48	1.59	1.36
Butyl octanoate	1551	4.76[b]	4.03[b]	3.26[a]	4.30[b]	3.28[b]
Methyl decanoate	1591	1.01[b]	1.38[b]	0.90[b]	0.73[a]	0.40[a]
Ethyl decanoate	1637	1520.80[a]	1708.43[b]	1543.24[a]	1558.22[a]	1748.34[b]
Isoamyl octanoate	1655	17.61[b]	20.28[c]	13.89[a]	16.05[b]	15.04[b]
Diethyl succinate	1671	2.10	1.94	1.98	2.79	2.48
(Z)-ethyl-4-decenoate	1691	483.16[a]	477.27[b]	355.60[a]	600.57[b]	606.12[b]
(Z)-ethyl-3-decenoate	1704	9.64[a]	9.14[a]	8.85[a]	14.52[b]	13.67[b]
(E)-ethyl-3-decenoate	1709	5.77[a]	4.63[a]	4.93[a]	8.55[b]	8.19[b]
β-phenylethyl acetate	1811	20.70[b]	26.85[c]	10.54[a]	17.88[b]	12.74[a]
Ethyl dodecanoate	1837	55.18[c]	56.42[c]	40.98[b]	47.58[b]	33.60[a]
Ethyl tetradecanaote	2045	1.67	1.89	1.61	1.18	1.87
Ethyl hexadecanoate	2248	1.99	2.12	2.19	1.06	0.83
All		4538.17[b]	4882.23[b]	4178.95[a]	4886.03[b]	5130.59[c]
Acids (mg/L)						
Butanoic	1624	0.04	0.06	0.10	0.07	0.10
Hexanoic	1828	0.25[a]	0.32[a]	0.49[b]	0.30[a]	0.31[a]
Octanoic	2051	13.40[a]	15.37[a]	12.76[a]	13.11[a]	17.39[b]
Decanoic	2262	5.31	6.26	5.18	5.94	6.55
All		19.00[a]	22.01[b]	18.52[a]	19.42[a]	24.35[b]
Alcohols (mg/L)						
Isoamyl	1208	64.76[c]	71.82[c]	41.93[a]	57.11[b]	43.86[b]
Hexanol	1347	0.97[b]	1.08[b]	0.89[b]	1.01[b]	0.57[a]
Heptanol	1449	0.44[b]	0.31[b]	–[a]	0.41[b]	–[a]
β-phenylethyl	1907	26.19[b]	27.57[b]	20.73[a]	25.60[b]	23.95[b]
All		92.36[b]	100.68[b]	63.55[a]	84.13[b]	68.38[a]
Terpenes (mg/L)						
Limonene	1186	0.003[a]	0.002[a]	0.006[a]	0.016[b]	0.027[b]
(E)-nerolidol	2034	tr[※]	tr	tr	tr	tr
All		0.003[a]	0.002[a]	0.006[a]	0.016[b]	0.027[c]
b. Volatiles[$] in the Cataratto wines by different strains						
Esters (μg/L)						
Ethyl butanoate	1036	2.82[b,c]	4.00[b]	1.31[a]	1.71[a]	3.44[b]
Ethyl 2-methylbutanoate	1051	tr[※]	tr	tr	tr	tr
Ethyl 3-methylbutanoate	1065	tr	tr	tr	tr	tr
Isoamyl acetate	1115	100.98[b]	71.06[b]	54.58[a]	49.00[a]	43.36[a]
Ethyl hexanoate	1226	89.92[c]	56.96[a]	67.07[b]	76.88[b]	86.58[c]
Hexyl acetate	1263	11.45[a]	9.63[a]	7.16[a]	7.52[a]	19.12[b]
Ethyl heptanoate	1326	0.42[b]	0.29[a]	0.26[a]	0.29[a]	0.57[b]
Methyl octanoate	1394	tr [a]	tr [a]	1.16[c]	0.43[b]	1.13[c]
Ethyl octanoate	1438	1109.08[b]	927.08[b]	784.92[a]	1117.99[b]	1083.86[b]
(Z)-ethyl-3-octenoate	1481	tr	tr	tr	tr	tr
Propyl octanoate	1517	0.76[a]	1.47[b]	0.44[a]	0.43[a]	1.03[b]
Ethyl nonanoate	1530	1.66[b]	0.84[a]	1.07[a]	0.86[a]	2.48[b]
Butyl octanoate	1551	2.82[b]	1.24[a]	1.27[a]	1.05[a]	3.19[b]
Methyl decanoate	1591	0.72[b]	0.52[a]	0.44[a]	0.58[a]	1.01[c]
Ethyl decanoate	1637	591.56[b]	609.89[b]	467.83[a]	606.93[b]	623.25[b]
Isoamyl octanoate	1655	8.72[b]	8.28[b]	4.29[a]	5.60[a]	6.42[a]
Diethyl succinate	1671	1.98[b]	0.87[a]	0.85[a]	0.79[a]	1.51[b]
(Z)-ethyl-4-decenoate	1691	257.45[a]	171.80[a]	205.20[a]	358.01[b]	581.13[c]
(Z)-ethyl-3-decenoate	1704	4.30[a]	4.93[a]	3.53[a]	5.39[a]	10.23[b]
(E)-ethyl-3-decenoate	1709	3.52[a]	2.76[a]	2.03[a]	3.10[a]	5.84[b]
β-phenylethyl acetate	1811	10.93[b]	11.63[b]	3.70[a]	7.35[a]	13.51[b]
Ethyl dodecanoate	1837	16.66[b]	11.04[a]	11.08[a]	15.28[b]	19.62[c]
Ethyl tetradecanaote	2045	3.38[b]	3.22[b]	1.06[a]	1.63[a]	3.83[b]
Ethyl hexadecanoate	2248	1.35	2.34	1.72	1.57	2.48
All		2220.48[b]	1902.85[a]	1620.97[a]	2262.39[b]	2513.59[b]
Acids (mg/L)						
Butanoic	1624	tr	tr	tr	tr	tr
Hexanoic	1828	1.34	1.50	1.09	1.48	1.00
Octanoic	2051	7.90[b]	8.03[b]	5.34[a]	8.22[b]	11.67[c]
Decanoic	2262	2.06	3.12	2.14	3.03	3.23
All		11.30[b]	12.65[b]	8.57[a]	12.73[b]	15.90[c]

Table 4 (*continued*)

Compounds	LRI[#]	VL1	EC1118	A2-40	A3-2	A4-9
b. Volatiles[$] in the Cataratto wines by different strains						
Alcohols (mg/L)						
Isoamyl	1208	36.52[b]	36.80[b]	25.91[a]	20.94[a]	22.75[a]
Hexanol	1347	0.61	0.79	0.41	0.32	0.94
Heptanol	1449	tr	tr	tr	tr	tr
β-phenylethyl	1907	9.13[b]	10.81[b]	4.88[a]	6.48[a]	14.48[b]
All		46.26[b]	48.40[b]	31.20[a]	27.74[a]	38.17[b]
Terpenes (mg/L)						
Limonene	1186	0.004[b]	0.002[b]	–[d,a]	0.016[c]	0.035[c]
(E)-nerolidol	2034	tr	tr	tr	tr	tr
All		0.004[b]	0.002[b]	tr[a]	0.016[c]	0.035[c]
c. Volatiles[$] in the Grillo wines by different strains						
Esters (μg/L)						
Ethyl butanoate	1036	2.03[b,*]	1.43[b]	1.31[b]	1.52[b]	1.08[a]
Ethyl 2-methylbutanoate	1051	0.25[a]	0.14[a]	0.60[b]	0.58[b]	0.37[a]
Ethyl 3-methylbutanoate	1065	0.36[a]	0.24[a]	0.50[a]	0.77[b]	0.46[a]
Isoamyl acetate	1115	11.57[b]	10.39[b]	7.02[a]	7.26[a]	8.44[a]
Ethyl hexanoate	1226	98.17[b]	59.25[a]	64.26[a]	58.33[a]	68.48[b]
Hexyl acetate	1263	4.18[a]	3.97[a]	3.57[a]	5.15[a]	7.90[c]
Ethyl heptanoate	1326	0.62[b]	0.20[a]	0.99[b]	1.59[c]	0.83[b]
Methyl octanoate	1394	tr[**]	tr	tr	tr	tr
Ethyl octanoate	1438	560.24[b]	587.21[b]	427.20[a]	671.81[b]	705.40[c]
(Z)-ethyl-3-octenoate	1481	0.51[a]	0.25[a]	1.45[b]	2.08[b]	1.12[b]
Propyl octanoate	1517	0.29[c]	0.27[c]	0.12[b]	0.11[b]	tr [a]
Ethyl nonanoate	1530	1.50	1.45	1.57	1.20	1.35
Butyl octanoate	1551	0.95	0.54	0.89	1.06	1.17
Methyl decanoate	1591	1.28[c]	0.63[b]	0.28[a]	0.62[b]	0.47[b]
Ethyl decanoate	1637	636.32[c]	551.81[b]	229.65[a]	431.63[b]	474.16[b]
Isoamyl octanoate	1655	4.09[a]	5.72[a]	3.20[a]	4.58[a]	9.05[b]
Diethyl succinate	1671	2.97[a]	1.49[a]	2.49[a]	4.03[b]	2.99[a]
(Z)-ethyl-4-decenoate	1691	98.25[a]	86.34[a]	121.63[a]	186.01[b]	170.16[b]
(Z)-ethyl-3-decenoate	1704	2.02[a]	1.76[a]	2.43[a]	4.11[b]	3.26[b]
(E)-ethyl-3-decenoate	1709	2.62[c]	1.20[a]	1.49[a]	2.51[c]	1.93[b]
β-phenylethyl acetate	1811	4.37[b]	4.08[b]	2.65[a]	5.21[b]	5.72[b]
Ethyl dodecanoate	1837	13.90[b]	12.15[b]	3.97[a]	8.27[a]	5.16[a]
Ethyl tetradecanaote	2045	3.06[b]	1.05[a]	1.18[a]	1.26[a]	1.88[a]
Ethyl hexadecanoate	2248	2.56[b]	tr[a]	tr[a]	tr[a]	1.12[b]
All		1452.11[b]	1331.54[b]	878.45[a]	1399.69[b]	1472.50[b]
Acids (mg/L)						
Butanoic	1624	0.05	0.13	0.13	0.05	0.05
Hexanoic	1828	1.55[b]	0.79[a]	0.49[a]	0.85[a]	0.75[a]
Octanoic	2051	4.50[c]	4.04[b]	1.68[a]	3.16[b]	3.56[b]
Decanoic	2262	2.20[b]	2.20[b]	0.40[a]	1.23[b]	0.80[a]
All		8.30[b]	7.16[b]	2.70[a]	5.29[b]	5.16[b]
Alcohols (mg/L)						
Isoamyl	1208	56.91[c]	59.82[c]	33.34[a]	40.42[b]	45.80[b]
Hexanol	1347	1.24[b]	0.76[a]	1.11[b]	1.23[b]	1.11[b]
Heptanol	1449	0.21	0.15	0.18	0.25	0.10
β-phenylethyl	1907	16.89[b]	17.38[b]	9.16[a]	15.90[b]	17.65[b]
All		75.25[b]	78.11[b]	43.79[a]	57.80[a]	64.66[b]
Terpenes (mg/L)						
Limonene	1186	0.006[b]	0.004[b]	–[∞,a]	0.025[c]	0.034[c]
(E)-nerolidol	2034	tr	tr	tr	tr	tr
All		0.006[b]	0.004[b]	tr[a]	0.025[c]	0.034[c]

[$]Listed in increasing retention index on a polar capillary GC column.
[#]Linear retention index calculated on CP-WAX 52 CB column.
[*]Different letters in the same row represent significant differences at $P<0.05$ by Duncan's multiple range test.
[∞]Not detected.
[**]< to 0.1 μg.

yeast strains used for fermentation. Conversely, each cultivar wine showed particular sensory descriptors, e.g. Inzolia samples were distinguished by “clearness” and “fruity” aroma, while Catarratto by “green reflexes”.

4. Discussion

Yeasts influence, both directly and indirectly, the chemical composition of wine, first transforming the sugars of the must into ethanol and carbon dioxide and then producing compounds, generated by secondary metabolic pathways, which increase the complexity and variability of the wine's chemical nature (Pretorius, 2000). The isolated strains showed high values of fermentation vigour, sulphite tolerance, fermentative power and low production of acetic acid and phenolic off-flavours. Further, the wines produced by the indigenous yeast strains show oenochemical parameters (Table 3) very similar to those of wines obtained using commercially selected strains which guarantee the production of quality wines. The activity of wine yeasts to decarboxylate ferulic and p-coumaric acids is related to the production of POF in winemaking. Since these substances were not identified in the wines analysed, it is possible to affirm that these yeast strains have a low POF activity, which is desirable in white-wine yeasts (Marullo et al., 2006). To evaluate the influence of these strains on the quality of the Grillo, Inzolia and

Table 5
Sensory scores for Grillo, Inzolia and Catarratto wines obtained by different yeast strains.

	Grillo					Inzolia					Catarratto				
	VL1	EC1118	A2-40	A3-2	A4-9	VL1	EC1118	A2-40	A3-2	A4-9	VL1	EC1118	A2-40	A3-2	A4-9
Colour intensity	4.94	4.83	4.94	4.64	4.86	6.36	6.44	6.18	6.20	6.04	4.05a[a]	5.12c	4.40b	4.86c	4.67b
Green reflexes	–	–	–	–	–	–	–	–	–	–	3.48	3.98	3.57	3.81	3.57
Clearness	–	–	–	–	–	6.76a	6.67a	7.13b	7.13b	7.07b	–	–	–	–	–
Fruity	–	–	–	–	–	4.91a	5.27b	5.02a	4.93a	5.62b	–	–	–	–	–
Citrus	3.47a	2.78a	2.97a	2.94a	3.31b	2.53	2.31	2.51	2.40	2.60	2.93b	2.64a	2.50a	2.81b	2.69a
Tree fruits	–	–	–	–	–	3.33	3.56	3.58	3.33	3.36	3.21b	3.50b	3.38b	3.33b	3.02a
Apple	2.86b	2.83b	2.69a	2.56a	2.47a	2.56	2.76	2.44	2.67	2.53	2.38	2.38	2.43	2.64	2.31
Pear	–	–	–	–	–	2.39	2.47	2.28	2.17	2.58	2.29	2.00	2.21	2.10	2.14
Exotic fruit	2.43b	2.88c	2.55b	2.12a	3.00c	2.91a	3.89c	3.07a	3.44b	3.33b	–	–	–	–	–
Banana	–	–	–	–	–	2.28b	2.00a	1.69a	1.81a	2.53b	2.02a	1.98a	1.98a	2.00a	2.38b
Dried fruit	–	–	–	–	–	2.27b	2.16b	2.04a	2.02a	1.93a	–	–	–	–	–
Floral	1.94b	1.89b	1.67a	2.42c	1.69a	2.60b	2.31a	2.24a	2.22a	2.29a	2.24b	2.17b	1.83a	2.02a	1.95a
Herbaceous/vegetative	3.11b	2.69a	3.08b	2.97a	3.28b	2.20b	1.91a	1.76a	2.27b	1.87a	2.31a	2.71b	2.29a	2.81b	2.21a
Pungent	3.11a	3.53b	4.00a	3.47b	3.36b	2.84	2.42	2.51	2.87	2.51	2.40	2.52	2.33	2.38	2.50
Acid	4.61a	5.50b	5.53b	5.17b	5.56b	4.96a	4.80a	4.84a	5.40b	5.02a	4.71a	5.29b	5.00b	4.79a	4.81a
Bitter	3.42a	3.89a	4.11b	3.83a	3.86a	3.49b	3.71b	3.07a	3.67b	3.09a	2.67	2.79	2.71	2.90	2.50

[a] Different letters in the same row represent significant differences at $P<0.05$ by Duncan's multiple range test.

Catarrato wines, the oenochemical, aroma compound and sensory descriptor data relative to the three cultivar underwent a Principal component analysis (PCA). The first two principal components accounted for 68.1% of total variance (41.4% of total variance for PC1 and 26.7% for PC2). Projection of samples in the space formed by the principal components, PC1 and PC2, are shown in Fig. 5; the variables most strongly correlated with the first two principal components are listed in Table 6. PC1, which evidenced that the wines of three different cultivars were clearly distinct from each other, displayed a strong correlation with octanoic and decanoic acids, most of esters and polyphenols. PC2 separated Cataratto wines from the others; the variables correlating most strongly with these axes were green reflexes, exotic fruit and bitter descriptors. The PCA demonstrated that the use of the isolated yeast strains did not influence the peculiarities of each cultivar.

Some interesting observations can be made considering each cultivar sample. All the samples obtained using both commercial and isolated strains were close to each other even if Grillo A2-40, Catarratto A4-9 and Inzolia A3-2 samples resulted rather separated from its cultivar group. From Table 6, isoamyl alcohol, ethyl (Z)-4-decenoate, ethyl (Z)-3-decenoate and ethyl (E)-3-decenoate were among the compounds most strongly correlated with the two principal components within each cultivar wine. As a result the selected strains, mainly A3-2 and A4-9, determined a lower amount of isoamyl alcohol and a higher amount of ethyl (Z)-4-decenoate, ethyl (Z)-3-decenoate and ethyl (E)-3-decenoate than commercial strains within each cultivar. This behaviour is in agreement with several authors who affirm that the use of different yeast strains during fermentation contributes considerably to variations in alcohol and ester profiles and concentrations in wine (Barrajón, Capece, Arévalo-Villena, Briones, & Romano, 2011; Duarte et al., 2010; Mateo, Jiménez, Pastor, & Huerta, 2001). Higher alcohols can have both positive and negative impacts on the aroma and flavour of wine depending on its concentration; they are considered favourable compounds when their total concentration is lower than 300 mg/L. Moreover, Patel and Shibamoto (2003) demonstrated that different *S. cerevisiae* yeast strains determine variations in isoamyl alcohol formation levels and Plata, Millán, Mauricio, and Ortega (2003) showed that the rate of isoamyl acetate synthesis is more strongly influenced by the availability of isoamyl alcohol than by enzyme activity itself. Isoamyl alcohol possesses a peculiar winey–brandy-like taste (Arctander, 1969), while isoamyl acetate smells of sweet and banana. Ethyl esters are one of the most important groups of aromatic compounds in wine, and their concentrations

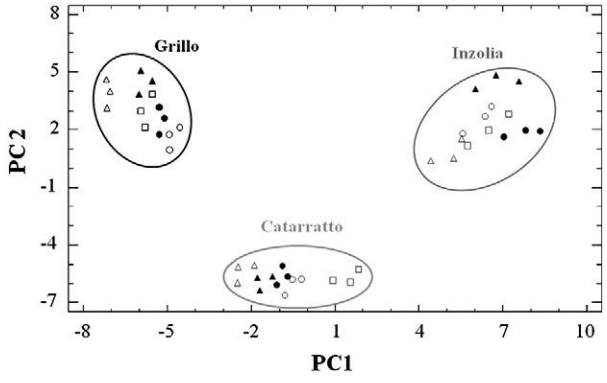

Fig. 5. Principal component (PC) analysis of eno-chemical composition, volatile composition and sensory data. Projection of the wine samples analysed in the space formed by the PC1 and PC2. ○ = VL-1; ● = EC1118; △ = A2-40; ▲ = A3-2; □ = A4-9.

Table 6
Results of the application of the PCA to the oenochemical, volatile composition and sensory data. Variables most strongly correlated with the PC1 and PC2.

Variables PC1	Variables PC2
All cultivars	
Octanoic	Green reflexes
Ethyl octanoate	Aroma exotic fruit
Decanoic	Bitter
Polyphenols	Citric acid
Ethyl decanoate	(Z)-ethyl-3-octenoate
Ethyl dodecanoate	
Inzolia	
(Z)-ethyl-4-decenoate	Limonene
Isoamyl alcohol	Methyl decanoate
Bitter	(E)-ethyl-3-decenoate
Total acidity	(Z)-ethyl-3-decenoate
Isoamyl acetate	
Grillo	
Ethyl decanoate	(Z)-ethyl-4-decenoate
Octanoic	Limonene
Free SO_2	(Z)-ethyl-3-decenoate
Acetaldehyde	Diethyl succinate
Isoamyl alcohol	
Catarratto	
Hexyl acetate	Green reflexes
(E)-ethyl-3-decenoate	Glycerol
Isoamyl octanoate	Ethyl decanoate
(Z)-ethyl-4-decenoate	Octanoic acid
Isoamyl alcohol	

depend on yeast strain, fermentation temperature, aeration, and sugar content. Ethyl esters of 2 and 4 decenoic acid together with those of 2–4 decadienoic are important flavour compounds responsible for a note of pear (Ashurst, 1999). In case of white wines such as Catarratto, Inzolia and Grillo the fruity notes, especially pear notes, due to ethyl esters of fatty acids and acetates of higher alcohols are widely appreciated by the consumer; thus the use of selected yeasts which are able to increase the pear notes (Z)-ethyl-4-decenoate, (E)-ethyl-3-decenoate, and (Z)-ethyl-3-decenoate and at the same time to reduce the alcohol and brandy odour (isoamyl alcohol) is of a great interest.

5. Conclusions

The microbiological, molecular, chemical and sensorial data reported here demonstrate that the *S. cerevisiae* strains A2-40, A3-2 and A4-9, isolated in Sicily, are able to produce quality white wines from grapes of the Grillo, Inzolia and Catarratto varieties. However, the longer fermentation times found for A2-40 greatly limit the possibility of using this strain on an industrial scale due to the greater costs relative to its use in controlled temperature fermentation. Instead, the strains A3-2 and A4-9 are able to produce, in a suitably short time, Cataratto and Grillo wines characterized not only by optimal oenochemical characteristics, in no way inferior to those obtainable with the best commercial strains selected in other geographical areas, but also with a distinctive aromatic profile which allows us to advise the use of these yeast strains in industrial wine production.

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