CHAPTER 3

Vin Santo

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Contents

Abstract

Vin Santo is the typical dessert wine produced in Tuscany, in particular, and in other areas of central and northern Italy, as well as on the Greek island of Santorini. It remains one of the most important "meditation wines", whose glamour starts with its ancient and mysterious origin. Italy is the country with the World's greatest tradition for sweet wine production. In this contest most of the steps in the Vin Santo making process are still linked to old local traditions. This chapter provides an overview of the different

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styles of Vin Santo produced in Italy together with its marketing. The main factors affecting grapes drying, alcoholic fermentation, maturation in barrels, are also described. So far there have been few scientific studies that have focused on Vin Santo. However, the increasing demand registered in the last few years for this kind of wine, is now greatly stimulating the research aimed to better manage its peculiar production process.

I. GENERAL DEFINITION AND PRODUCTION AREAS

Historically, ''Vin Santo,'' or as it is also known, ''Vinsanto'' or ''Vino Santo'' (literally ''Saint wine''), is a traditional term that relates to a group of dessert wines (*passito* wines) that have been produced for a long time in Toscana (Tuscany), in particular, and in other areas of central and northern Italy, as well as on the Greek island of Santorini (Fig. 3.1).

Today, European Union legislation (Reg. EU N° 401/2010) defines and recognizes ''Vin Santo'' by the following synthetic definition:

> (Italy)—''Vin Santo,'' ''Vino Santo,'' ''Vinsanto''[1]
> ''Historical-traditional term related to some wines produced in regions Toscana, Marche, Umbria, Emilia Romagna, Veneto, and

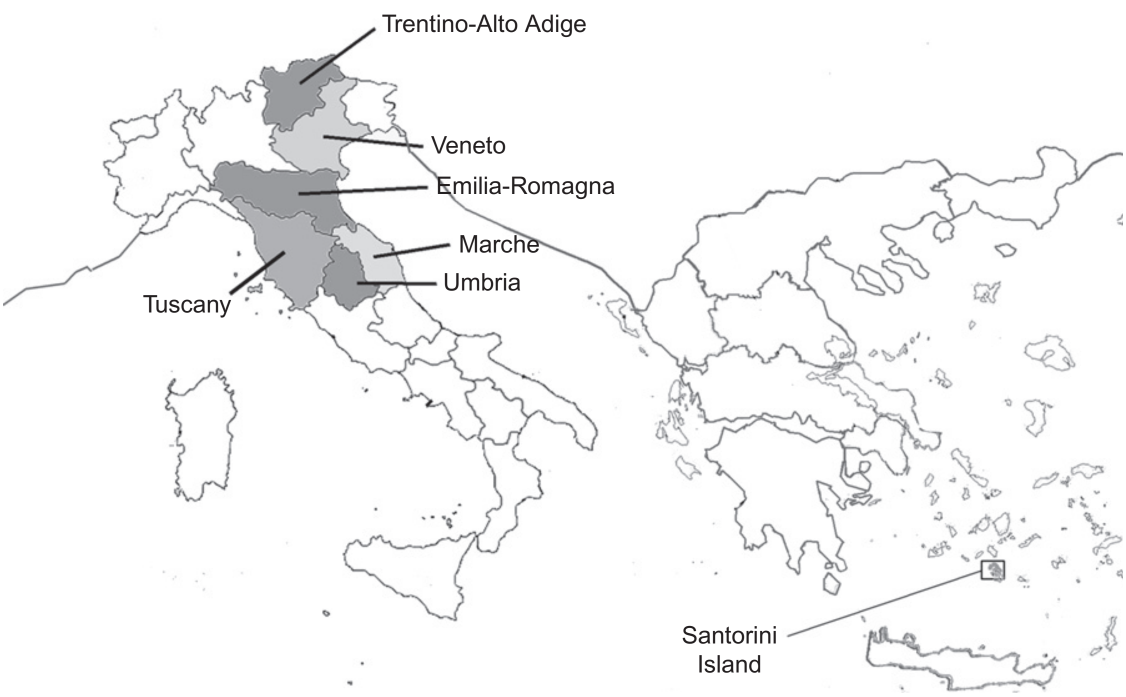

FIGURE 3.1 Vin Santo production areas. (according to EU Reg. N° 401/2010)

[1] PDO (protected designation of origin) or PGI (protected geographical indication), supplemented by the reference to the categories of grapevine products as referred to in Annex XIb of Regulation (EC) No 1234/2007.

> Trentino Alto Adige. It refers to the particular wine typology and to the corresponding and complex production method which implies storage and wine grapes drying in suitable and aerated places for a long aging period into traditional wooden containers. (. . .)
> The term is still in use and it is mentioned in detail in the Protected Designation of Origin (PDO) specifications, a typology which is largely known and appreciated all over the world.'' (. . .)
> (*Greece*)—''Vinsanto''[1]
> ''Wine of 'Santorini' PDO produced in the complex of Santo Erini-Santorini of the islands of 'Thira' and 'Thirasia' from grapes left in the sun.''[1]

This EU definition already highlights well the difference between Vin Santo produced in Italy and that produced on Santorini Island, Greece, which arise mainly from the different systems for the grape drying: in Italy, in mild *condition* (aerated places), and in Greece, under the sun.

A. Vin Santo of the Italian regions

Many excellent dessert wines are made throughout Italy, although perhaps the most famous and renowned is Vin Santo. To date, Italian Vin Santo is recognized and protected by EU regulations, as a Qwpsr ''Quality wine produced in specific regions'' (*Vqprd: vini di qualità prodotti in regioni determinate*), under the specific PDO (Italian: DOC or DOCG: *Denominazione di Origine Controllata or Denominazione di Origine Controllata e Garantita*) (Table 3.1).

As will be explained in more detail below, all Italian Vin Santo production traditionally follows the same basic scheme, although there are major differences in the grape varieties used and in the degree of grape drying; these lead to the different types and styles of Vin Santo.

In all production areas, Vin Santo is made by starting with the choice of the best grapes (*scelti*) of the white varieties that are grown in each zone. A blend with predominantly non-varietal grapes (such as Trebbiano or Garganega) is used, to which aromatic grapes (such as Malvasia Bianca del Chianti) or semi-aromatic grapes (such as Grechetto) are often added in small amounts, to enhance the aroma of the Vin Santo toward a more aromatic style. In Tuscany especially, as well as these Vin Santo made with white grapes, the rare *Vin Santo occhio di pernice* (Vin Santo, eye of the partridge) is also produced, which is obtained from red grape varieties, and which normally refers to the use of Sangiovese and Canaiolo grapes.

Once picked, the grapes are left to dry indoors under ambient conditions. This continues for as long as is necessary to achieve the sugar concentration that is required for each specific style of Vin Santo (26% minimum, up to 45–48% sugar). The dried grapes are then pressed and

TABLE 3.1 Definitions of Vin Santo

From REGULATION (CE) N. 1512/2005, September 15, 2005
Italy *Wine category*: Quality wine produced in specific regions or Qwpsr (*Vini di qualità prodotti in regioni determinate*—Vqprd) *Traditional terms*: Vin Santo/Vino Santo/Vinsanto *Wines concerned* (DOC): Bianco dell'Empolese, Bianco della Valdinievole, Bianco Pisano di San Torpé, Bolgheri, Candia dei Colli Apuani, Capalbio, Carmignano, Colli dell'Etruria Centrale, Colline Lucchesi, Colli del Trasimeno, Colli Perugini, Colli Piacentini, Cortona, Elba, Gambellera, Montecarlo, Monteregio di Massa Marittima, Montescudaio, Offida, Orcia, Pomino, San Gimignano, San'Antimo, Val d'Arbia, Val di Chiana, Vin Santo del Chianti, Vin Santo del Chianti Classico, Vin Santo di Montepulciano, Trentino *Traditional complementary terms*: *Occhio di pernice* *Wine concerned* (DOC): Bolgheri, Vin Santo Di Carmignano, Colli dell'Etruria Centrale, Colline Lucchesi, Cortona, Elba, Montecarlo, Monteregio di Massa Marittima, San Gimignano, Sant'Antimo, Vin Santo del Chianti, Vin Santo del Chianti Classico, Vin Santo di Montepulciano.
Greece *Wine category*: Quality wine produced in specific regions (Qwpsr) and Quality liqueur wine produced in specific regions (Qlwpsr) *Traditional terms*: Vinsanto *Wines concerned*: (ΟΡΑΠ) Santorini

the juice is left to undergo fermentation, following which the wine is matured for a long time in small barrels made from neutral wood.

The color of Vin Santo can range from pale to dark amber, and even to orange. The typical flavors of Vin Santo include raisin, nutty, and hay notes, with honey and cream attributes.

As is well known, and especially for the old-style Vin Santo, these wines have a generally high alcohol content (14% and above) that is combined with different low levels of residual sugar, referring to these wines as semi-dry or dry styles that are ideal after meals. A slightly sweet style (*amabile*) and sweet style (*dolce*) is also produced, which are appreciated at their best after a dessert, or accompanying the dessert itself.

The different Vin Santo styles range from less structured products to full-bodied wines that are rich in extracts and flavors and that have a taste that is very full and generous. This can thus please the palate more than a liquor, which also makes such Vin Santo fully appreciated when sampled alone, away from the consumption of other foods (meditation wine).

The Italian Vin Santo is therefore a complex, ancient, and traditional wine, and even today it well deserves to be called "the wine of hospitality."

B. Vinsanto of Santorini

This famous dessert wine is now only produced on the Greek island of Santorini, where its production is also recognized and protected by EU regulations, as the PDO Santorini (Greek: OPAP, *Onomasia Proelefseos Anoteras Piotitos*) (Table 3.1).

Vinsanto of Santorini is made from white grape varieties that have been grown in Santorini for a long time: a blend where Assyrtiko is the majority grape variety and Aidani is blended for aroma enhancement. The making of Vinsanto in Santorini also has a long history, and it still goes on today. Briefly, the Assyrtiko and Aidani grapes are harvested in early August and left to dry in the sun for 8–10 days. The grapes are then crushed and left to ferment, and the wine is then aged in oak barrels. It is produced as sweet style (Qlwpsr) or naturally sweet style (Qwpsr).

The final product is a naturally fermented dessert wine that has a copper to golden brown color. The mix of raisins, honey, and spices with a sweet and rich velvet-like texture is balanced by the high acidity that arises from the use of the Assyrtiko grapes. This makes the taste and bouquet of Santorini Vinsanto very particular.

II. HISTORY

The glamor of Vin Santo wine starts with the mysterious origin of its name. Indeed, this origin is still a matter of discussion, with different hypotheses having been generated over the years. In this context, within European Union legislation (Reg. EU, No 401/2010), it is reported that "*With regard to the origin of the term, numerous hypotheses have been formulated, most of them connected to the Middle Ages. The most reliable is strictly connected to the religious value of wine. This wine was considered quite extraordinary and boasted miraculous virtues. It was commonly used when celebrating the Saint Mass and this can explain the term 'Saint wine' (vinsanto).*"

However, other origins have been reported, among which one relates that in the year 1439 a Council was held in Florence for the unification of the catholic and orthodox churches. During a banquet, a wine of local production was served, and it is said that when drinking it, Bessarone, an ancient Greek patriarch, exclaimed: "This is wine of Xantos," referring to the wine of the Greek island of Xantos. This word was apparently misunderstood, and since then the name of ''Vin Santo'' has remained. Although certainly the more fascinating, this story is perhaps also the less likely, as in all probability the name derives from the link with important religious festivals of the Christian calendar. Indeed, the grapes were often left to dry until the feast of All Saints or until Christmas, and then pressed or bottled during Easter.

The origins of Vin Santo as a typical wine have also been lost in time. Indeed, the appearance of Vin Santo in the ancient literature is also controversial. Celentano (2004) in his book entitled Vini d'italia etc, wrote Vino Santo Severino reported that Sante Lancerio, bottelier (cellarman) to Pope Paul III (1534–1559), in his manuscript entitled *Della qualità dei vini* wrote ''*Vino Santo Severino*'' when talking of a sweet wine from Apulia. However, we believe that as for the case of ''Xantos'', this name referred to the village of San Severo (Apulia) and not to a ''Saint'' wine. Instead, and more likely, the name appears to have been used for the first time in ''*Enologia in Toscana*'', a book written by Cosimo Villifranchi and published in Florence in 1773.

Beyond these reports, the origins of Vin Santo are certainly ancient. On the other hand, Italy has always had a wide and varied tradition of sweet dessert wines. This tradition came to Italy directly from Greek civilization, as the drying allowed better conservation of the grapes during winter, as well as the obtaining of musts with high sugar concentrations, thus resulting in the production of wines that were more stable, and therefore easier to transport (Scienza, 2006).

III. ITALIAN VIN SANTO

Here we will discuss the Vin Santo produced in Italy because the production techniques and particularities of Santorini Vin Santo are more similar to those of sweet wines of aromatic styles produced all around the coasts of the Mediterranean Sea (as Passito di Pantelleria, or Greco di Bianco—passito, etc.).

A. Classification and style

As outlined above, Vin Santo wines are essentially a group within the larger collection of dessert wines that are made mainly from non-aromatic grapes, and which in Italy are called ''vino *passito*'' or *passito.* This term ''*passito*'' generally means ''wine made from dried grapes'' (Italian: *vino da uve passite*) (Table 3.2).

Table 3.3 lists the non-aromatic *passito* wines, other than Vin Santo.

On the basis of the characteristics presented that arise from the specific production technique, different styles are recognized within the Vin Santo

TABLE 3.2 Main grape-drying systems for the production of *passito* wines

On the vine		– Late harvest – Torsion of pedicel or cutting fruit branch – Frozen grapes – Noble rot
Off the vine	Natural drying	– Under the sun (on special mats of reeds or straw) – Ventilated room (on special mats or hanging the grapes up)
	Forced drying	– Artificial ventilation – Thermo-conditioned tunnel

that is on the market (Table 3.4). These derive mainly from the alcohol, residual sugar, and net extract. In particular, depending on the grape variety, we can distinguish two main styles: Vin Santo (without other specifications), obtained from white grapes, and the rarer *rosé* style *Vin Santo occhio di pernice*, which is obtained from red grapes or from a mix of red and white grapes.

Depending on whether there is more or less alcohol in a wine and on the residual sugar, and therefore relating to the relative perception of sweetness and alcohol content, within these two above-mentioned categories there are other main Vin Santo styles that can be recognized: a dry style (Italian *secco* or *asciutto*: with 16–19% alcohol, and 10–50 g L^{-1} sugar), a slightly sweet and a sweet style (*amabile* and *dolce*: with 14–16% alcohol, and up around to 100 g L^{-1} sugar), and a rare extremely sweet style (with 14–16% alcohol, and 150–200 g L^{-1} sugar, which can rise to 200–250 g L^{-1} residual sugar in exceptional cases). Similarly, in relation to the content of non-sugar substances (net extract) and to the overall perception in the mouth, Vin Santo can be classified as light structured, medium structured, or full-bodied wine.

B. Chemical and organoleptic characteristics

Tachis (1988) reported the mean composition of Vin Santo, on the basis of about 200 samples produced over the years in different Italian Regions and mainly in Tuscany (Fig. 3.2). From this investigation, it is seen that in the past most Vin Santo were characterized by an alcohol content of between 16% and 17%. Slightly fewer had 15–16% alcohol, with these Vin Santo together accounting for some 70% of total production. Only 10% of the sample had alcohol levels close to 15%, while 9% of the sample had an alcohol content from 18% to 21%.

TABLE 3.3 The non-aromatic *passito* wines (other than Vin Santo) produced in Italy from non-aromatic and semi-aromatic grape varieties

Regions	Wines concerned (DOC or DOCG regulation)	Grape varieties
Valle d'Aosta	Valle d'Aosta Nus—Malvoise passito DOC (D.M. July 7, 2008)	Malvoise di Nus (Pinot grigio)
Piemonte	Caluso passito DOC (D.M. June 25, 1998)	Erbaluce
Lombardia	Sforzato (Sfurzat) di Valtellina DOCG (D.M. March 19, 2003)	Nebbiolo (min 90%)
Veneto	Amarone della Valpolicella DOC (D.D. September 14, 2007) Amarone della Valpolicella classico DOC Amarone della Valpolicella Valpantena DOC	Corvina veronese (min 40%); Corvinone (max 50%); Corvina veronese + Corvinone (max 80%); Rondinella (5–30%); other grapes (max 15%)
	Colli di Conegliano—Torchiato di Fregona DOC (D.M. December 9, 1997)	Prosecco (39%); Verdino (min 30%); Boschera (min 25%)
	Colli di Conegliano— Refrontolo passito DOC	Marzemino (min 95%)
	Recioto di Gambellara classico DOCG. (D.D. August 8, 2008)	Garganega
	Recioto di Soave DOCG (D.D. September 19, 2001) Recioto di Soave classico DOCG	Garganega (min 70%); Chardonnay + Pinot bianco + Trebbiano di Soave (max 30%)
	Recioto della Valpolicella DOC (D.D. September 14, 2007) Recioto della Valpolicella—classico DOC Recioto della Valpolicella—Valpantena DOC	Corvina veronese (min 40%); Corvinone (max 50%); Corvina veronese + Corvinone (max 80%); Rondinella (5–30%); other grapes (max 15%)
Friuli Venezia Giulia	Colli Orientali del Friuli Picolit DOCG (D.D. March 30, 2006)	Picolit
	Ramandolo DOCG (D.D. October 10, 2001)	Verduzzo

Emilia Romagna	Albana di Romagna passito DOCG (D.D. August 31, 2004)	Albana
	Albana di Romagna passito riserva DOCG	
Liguria	Cinque Terre Sciacchetrà passito DOC (D.D. March 3, 2000)	Bosco (min 40%); Arbarola + Vermentino (max 40%)
	Cinque Terre Sciacchetrà riserva DOC	
Umbria	Montefalco— Sagrantino passito DOCG (D.M. November 5, 1992)	Sagrantino
Marche	Offida—Passerina passito DOC (D.D. May 23, 2001)	Passerina
	Lacrima di Morro d'Alba passito DOC (D.D. July 18, 2005)	Lacrima (min 85%)
Abruzzo	Controguerra—passito bianco DOC (D.M. March 21, 2006)	Trebbiano toscano + Malvasia + Passerina (min 60%)
	Terre Tollesi—rosso passito DOC (D.D. July 23, 2008)	Montepulciano (min 90%)

Italian legislation: D.M., Decree Ministry of Agriculture; D.D., Decree Director—Agriculture Ministry.

TABLE 3.4 Vin Santo (Official denominations and recognitions according to Italian law, and relative main parameters)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
Trentino	Trentino—Vin Santo DOC (D.D. June 8, 2010)	Nosiola (85% min)	10/16	24	30	22.5
	Trentino superiore—Vin Santo DOC (D.D. June 8, 2010)	Nosiola (85% min)	11/18	48	30	23
Veneto	Gambellara classico—Vin Santo DOC (D.D. December 19, 2008)	Garganega (80% min); Chardonnay/Pinot bianco/Trebbiano di Soave (20% max)	.../16	48	40	26
Emilia Romagna	Colli Piacentini—Vin Santo DOC (D.M. June 30, 1998)	Ortrugo/Sauvignon/ Trebbiano romagnolo/ Malvasia di Candia (80% min)	.../16	48	35	20
	Colli Piacentini—Vin Santo di Vigoleno DOC (D.M. June 30, 1998)	Marsanne/ Beverdino/ Sauvignon/ Ortrugo/Trebbiano romagnolo (80% min)	.../18	60	30	22

Toscana	Bianco della Valdinievole—Vin Santo DOC (D.D. May 14, 2007)	Trebbiano toscano (70% min); Canaiolo/Vermentino (30% max)	14/17 *Amabile*: *13/17* *Dolce: 12/17*	24	35	20
	Bianco dell'Empolese—Vin Santo DOC (D.P.R. April 18, 1989)	Trebbiano toscano (80% min); Malvasia del Chianti (8% Max)	*Secco: 16/17* *Amabile: 15/17*	24	35	23
	Bianco Pisano di San Torpé—Vin Santo DOC (D.M. July 14, 1997)	Trebbiano toscano (75% min)	. . ./16	24	35	23
	Bianco Pisano di San Torpé DOC (D.M. July 14, 1997)	Trebbiano toscano (75% min)	. . ./16	36	35	23
	Bolgheri—Vin Santo occhio di pernice DOC (D.D. June 14, 2001)	Sangiovese (50–70%); Malvasia nera (30–50%)	14.5/16	24	30–35	26
	Bolgheri—Vin Santo occhio di pernice riserva DOC (D.D. June 14, 2001)	Sangiovese (50–70%); Malvasia nera (30–50%)	14.5/16	36	30–35	26
	Candia dei Colli Apuani DOC (D.M. April 14, 1997)	Vermentino (70–80%); Albarola (10–20%); Trebbiano toscano/Malvasia (5% max)	14/16.5	24	35	25
	Vin Santo di Carmignano DOC (D.M. July 14, 1998)	Trebbiano toscano/Malvasia del Chianti (75% min)	13/16 *Secco: 13/+3% max potential; Amabile: 13/+3% min potential*	24	35	21

(*continued*)

TABLE 3.4 (*continued*)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
	Vin Santo di Carmignano—riserva DOC (D.M. July 14, 1998)	Trebbiano toscano/Malvasia del Chianti (75% min)	13/16 *Secco: 13/+3% max potential; Amabile: 13/+3% min potential*	36	35	21
	Vin Santo di Carmignano—occhio di pernice DOC (D.M. July 14, 1998)	Sangiovese (50% min)	14/16	24	35	26
	Vin Santo di Carmignano—occhio di pernice DOC (D.M. July 14, 1998)	Sangiovese (50% min)	14/16	36	35	26
	Colli dell'Etruria Centrale—Vin Santo DOC (D.M. May 24, 1997)	Trebbiano toscano/Malvasia del Chianti (70% min)	14/16 *Secco:14/+2% max potential; Amabile: 13/+3% min potential*	24	35	21
	Colli dell'Etruria Centrale—Vin Santo riserva DOC (D.M. May 24, 1997)	Trebbiano toscano/Malvasia del Chianti (70% min)	14/... *Secco: 14/+2% max potential; Amabile: 13/+3% min potential*	36	35	21

Colli dell'Etruria Centrale—Vin Santo occhio di pernice DOC (D.M. May 24, 1997)	Sangiovese (50% min)	14/16.6	24	35	26
Colline Lucchesi—Vin Santo DOC (D.M. July 8, 1997)	Grechetto/Trebbiano/Chardonnet, Greco/Sauvignon/Vermentino	.../16	24	35	26
Colline Lucchesi—Vin Santo occhio di pernice DOC (D.M. July 8, 1997)	Sangiovese (45–70%); Canaiolo/Ciliegiolo (30% max); Merlot (15% max)	.../16	24	35	26
Cortona Vin Santo DOC (D.D. September 1, 1999)	Trebbiano toscano/Grechetto/Malvasia del Chianti (80% min)	15/17	27	35	24
Cortona Vin Santo riserva DOC (D.D. September 1, 1999)	Trebbiano toscano/Grechetto/Malvasia del Chianti (80% min)	14.5/17	66		24
Cortona Vin Santo occhio di pernice DOC (D.D. September 1, 1999)	Sangiovese/Malvasia nera (80% min)	15/18	96		25
Elba Vin Santo DOC (D.M. July 9, 1967)	Trebbiano toscano (50% min), Ansonica/Vermentino (50% max)	*Secco: 14/16* *Amabile: 13/16*	24	35	22

(*continued*)

TABLE 3.4 (*continued*)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
	Elba Vin Santo riserva DOC (D.M. July 9, 1967)	Trebbiano toscano (50% min), Ansonica/Vermentino (50% max)	*Secco: 14/16* *Amabile: 13/16*	36	35	22
	Elba Vin Santo occhio di pernice DOC (D.M. July 9, 1967)	Sangiovese (60% min) White grapes (10% max)	14/16	36	35	26
	Montecarlo Vin Santo DOC (D.M. October 1, 1985)	Trebbiano toscano (40–60%) Semillon/Pinot grigio/Pinot bianco/Sauvignon/Roussanne	*Secco: 14/16* *Amabile: 13/16*	24	35	21
	Montecarlo Vin Santo riserva DOC (D.M. October 1, 1985)	Trebbiano toscano (40–60%) Semillon/Pinot grigio/Pinot bianco/Sauvignon/Roussanne	16/...	36	35	21
	Montecarlo—Vin Santo occhio di pernice DOC (D.M. October 1, 1985)	Sangiovese (50–75%) Canaiolo nero/Ciliegiolo/Colorino/Malvasia nera/Sirah/Cabernet/Merlot (10–15% max)	14/16	36	35	26

Monteregio di Massa Marittima—Vin Santo DOC (D.M. October 3, 1994)	Trebbiano toscano (70% min)	*Secco: 14/16* *Amabile: 13/+ 3% min potential*	24	35	21
Monteregio di Massa Marittima-Vin Santo occhio di pernice DOC (D.M. October 3, 1994)	Sangiovese (50–70%); Malvasia nera (10–50%)	14/16	36	35	26
Montescudaio—Vin Santo DOC (D.M. October 25, 1999)	Trebbiano (50%)	. . ./16	36	35	23
Orcia—Vin Santo DOC (D. D. February 14, 2000)	Trebbiano toscano/ Malvasia del Chianti (50% min)	13/16	24	35	23
Pomino—Vin Santo DOC (D.D. February 7, 2005)	Pinot bianco and grigio/Chardonnet (70% min)	14.5/15.5	24	35	23
Pomino—Vin Santo rosso DOC (D.D. February 7, 2005)	Sangiovese (50% min); Pinot nero/Merlot (50% Max)	14.5/15.5	24	35	23
San Gimignano—Vin Santo DOC (D.M. August 8, 1996)	Trebbiano (30% min); Malvasia del Chianti (50% max); Vernaccia di San Gimignano (20% Max)	14.5/16.5	28	35 (38)	21

(*continued*)

TABLE 3.4 (*continued*)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
	San Gimignano –Vin Santo occhio di pernice DOC (D.M. August 8, 1996)	Sangiovese (50% min)	14.5/16.5	28	35 (38)	25
	Sant'Antimo—Vin Santo DOC (D.M. January 18, 1996)	Trebbiano toscano/ Malvasia del Chianti (79% min)	*Secco:14/16* *Amabile: 13/16*	24	35	21
	Sant'Antimo—Vin Santo riserva (D.M. January 18, 1996)	Trebbiano toscano/ Malvasia del Chianti (79% min)	*Secco:14/16* *Amabile: 13/16*	36	35	21
	Sant'Antimo—Vin Santo occhio di pernice DOC (D.M. January 18, 1996)	Sangiovese (50–79%); Malvasia nera (30–50%)	14/16	24	35	26
	Sant'Antimo—Vin Santo occhio di pernice riserva DOC (D.M. January 18, 1996)	Sangiovese (50–79%); Malvasia nera (30–50%)	14/16	36	35	26
	Val d'Arbia—Vin Santo DOC (D.M. May 30, 85)	Trebbiano toscano/ Malvasia del Chianti (70–90%); Chardonnay (10–39%)	*Dolce: 12/17* *Semisecco: 13/17* *Secco: 14/17*	24	35	21

Val di Chiana—Vin Santo DOC (D.M. December 30, 1989)	Trebbiano toscano/ Malvasia del Chianti (50% min)	*Secco: 12/15* *Amabile 11.9/15*	24	35	22
Val di Chiana—Vin Santo riserva (D.M. December 30, 1989)	Trebbiano toscano/ Malvasia del Chianti (50% min)	*Secco: 12/15* *Amabile: 11.9/15*	36	35	22
Vin Santo del Chianti Classico DOC (D.M. October 24, 1995)	Trebbiano toscano/ Malvasia del Chianti (70% min)	*Secco: 14/16* *Amabile: 13/16*	24	35	21
Vin Santo del Chianti Classico DOC (D.M. October 24, 1995)	Trebbiano toscano/ Malvasia del Chianti (70% min)	*Secco: 14/16* *Amabile: 13/16*	36	35	21
Vin Santo del Chianti Classico—occhio di pernice DOC (D.M. October 24, 1995)	Sangiovese (50% min)	14/17	24	35	26
Vin Santo del Chianti Classico—occhio di pernice DOC (D.M. October 24, 1995)	Sangiovese (50% min)	14/17	36	35	26
Vin Santo del Chianti [—Colli Aretini, —Colli Fiorentini, —Colli Senesi, —Colline Pisane, —Montalbano, —Montespertoli, —Rufina] —riserva DOC (D.M. August 28, 1997)	Trebbiano toscano/ Malvasia del Chianti (70% min)	13/15.5–16 *Secco: 13/+ 3% max potential; Amabile: 13/+ 3% min potential*	24	35	21

(*continued*)

TABLE 3.4 (*continued*)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
	Vin Santo del Chianti [– Colli Aretini, —Colli Fiorentini, —Colli Senesi, —Colline Pisane, —Montalbano, —Montespertoli, —Rufina] DOC (D.M. August 28, 1997)	Trebbiano toscano/ Malvasia del Chianti (70% min)	13/15.5–16 *Secco: +3% max potential; Amabile: +3% min potential*	36	35	21
	Vin Santo del Chianti [– Colli Fiorentini, —Colli Senesi, —Montespertoli, —Rufina] —occhio di pernice DOC (D.M. August 28, 1997)	Sangiovese (50% min)	14/16.5–17	24	35	26
	Vin Santo del Chianti [—Colli Fiorentini, —Colli Senesi, —Montespertoli, —Rufina] —occhio di pernice riserva DOC (D.M. August 28, 1997)	Sangiovese (50% min)	14/16.5–17	36	35	26

Vin Santo di Montepulciano DOC (D.M. October 21, 1996)	Trebbiano toscano/ Malvasia del Chianti/Grechetto (70% min)	15/17	36	35	20
Vin Santo di Montepulciano riserva DOC (D.M. October 21, 1996)	Trebbiano toscano/ Malvasia del Chianti/Grechetto (70% min)	14/17	60	35	22
Vin Santo di Montepulciano—occhio di pernice DOC (D.M. October 21, 1996)	Sangiovese (50% min)	15/18	96	35	25
Capalbio—Vin Santo DOC (D.D. May 21, 1999)	Trebbiano del Chianti (50% min)	14/16 *Amabile: 14/+ 3–6% min potential*	24	35	21
Colli dell'Etruria Centrale —Vin Santo DOC (D.M. May 24, 1997)	Trebbiano toscano/ Malvasia del Chianti (70% min)	14/. . . *Secco: 14/+ 2% max potential; Amabile: 14/+ 3% min potential*	24	35	21
Colli dell'Etruria Centrale— Vin Santo riserva DOC (D.M. May 24, 1997)	Trebbiano toscano/ Malvasia del Chianti (70% min)	14/. . . *Secco: 14/+2% max potential; Amabile: 14/+ 3% min potential*	36	35	21

(*continued*)

TABLE 3.4 (*continued*)

Region	Wines concerned (DOC regulations)	Grape varieties	Alcohol actual/total[a] (% min)	Aging (months)	Wine yield (Max % of fresh grape)	Net extract (min, g L^{-1} min)
	Colli dell'Etruria Centrale—Vin Santo occhio di pernice DOC (D.M. May 24. 1997)	Sangiovese (50% min)	14/16.50	24	35	26
Umbria	Colli Perugini—Vin Santo DOC (D.M. September 10, 1999)	Trebbiano toscano (50% min); Malvasia (10% max)	13/16	24	40	25
	Colli del Trasimeno—Vin Santo DOC (D.M. January 7, 1998)	Trebbiano toscano (40%); Grechetto/Chardonnay/Pinot bianco/Pinot grigio (30% min)	14/16	18	40	20
Marche	Offida—Passerina passito DOC (D.D. May 23, 2001)	Passerina (85% min)	13/15	36	40	25

Italian legislation: D.P.R., Decree of President of Republic; D.M., Decree Ministry of Agriculture; D.D., Decree Director—Agriculture Ministry.
[a] Sum of actual alcohol and potential alcohol (residual sugar × 0.6).

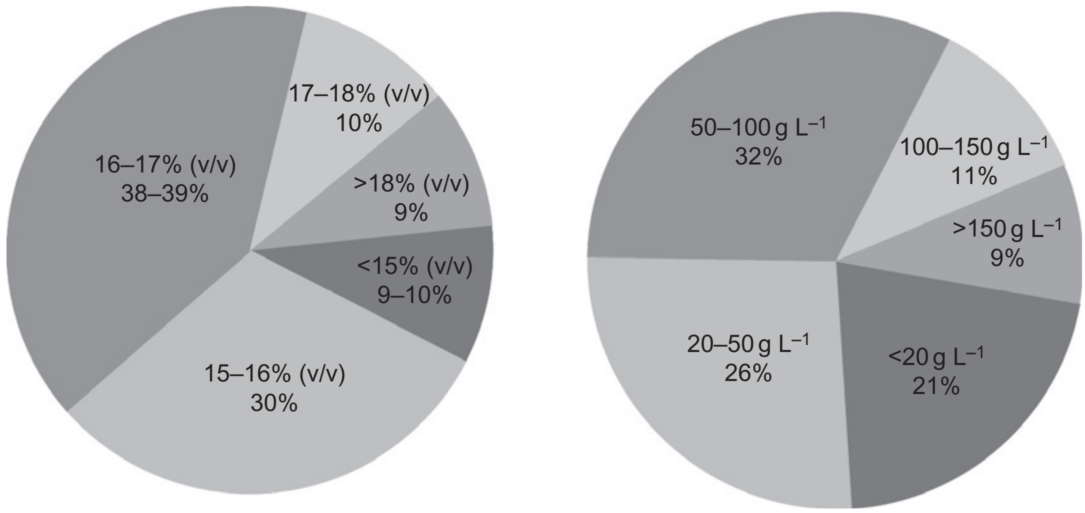

FIGURE 3.2 Percent distribution of Vin Santo, by ethanol (left) and sugar (right) concentrations. (elaborated from Tachis, 1988)

For the residual sugar, the Vin Santo on the market were divided almost equally between those of the dry style, with a sugar content <50 g L^{-1} (47%), and those of the slightly sweet to sweet style (50–150 g L^{-1} sugar, and more), which together accounted for the remaining 53% of production. Within these styles, those that were very dry (<20 g L^{-1} sugar) represented about 21%, while the very sweet accounted for 9–10% of the total.

In relation to the other main quality parameters of Vin Santo, Tachis (1988) reported the findings summarized in Table 3.5, which are related to Vin Santo produced mainly in Tuscany over the previous years. As we can see, among the products, the various parameters showed large variabilities that help to explain the perceived differences between the different styles of Vin Santo. In particular, the minimum total acidity reported was 4 g L^{-1}, a value more characteristic of normal red wine, not of Vin Santo. The difference between the minimum and maximum values of net extract (22 and 40 g L^{-1}, respectively) was also remarkable, with this parameter more than any other related to the perception of the texture in wine.

Later, other data on Vin Santo composition were also published by Bucelli *et al.* (1998) and Stella *et al.* (1998), who focussed their attention on the Tuscany production of Vin Santo, although they did not consider the *occhio di pernice* ones (Table 3.6). Here, it can be seen that with respect to the compositions considered previously, these here show less variability across all of the parameters. Moreover, the maximum alcohol content from 21% drops to 18.5%, while the volatile acidity is quite low, despite the high alcohol levels and the oxidative conditions in which these wines evolve respect to normal vinifications. The net extract instead decreases, especially in the maximum values.

TABLE 3.5 Mean composition of Vin Santo from different Italian regions (from Tachis, 1988)

	Min	Max
Total acidity (g L^{-1} tartaric acid)	4	8.8
Volatile acidity (g L^{-1} acetic acid)	0.7	1.25
Ash (g L^{-1})	1.6	4
Net extract (g L^{-1})	22	40
Glycerol (g L^{-1})	2	21
Ethyl acetate (mg L^{-1})	150	350

TABLE 3.6 Compositions of Tuscany Vin Santo (data elaborated from Bucelli *et al.*, 1998 and Stella *et al.*, 1998)

	Min	Max
Residual sugar (g L^{-1})	13.74	108.45
Actual alcohol (%, v/v)	14.68	18.54
Total alcohol[a] (%, v/v)	17.28	22.05
Total acidity (g L^{-1} tartaric acid)	4.92	8.81
Volatile acidity (g L^{-1} acetic acid)	0.77	1.35
Ash (g L^{-1})	1.76	3.00
Net dry extract (g L^{-1})	20.95	34.83
Glycerol (g L^{-1})	8.68	13.79
Acetaldehyde (mg L^{-1})	55.00	93.50
Ethyl acetate (mg L^{-1})	157.00	352.00
Total higher alcohols (mg L^{-1})	222.00	353.00

[a] Sum of actual alcohol and potential alcohol (residual sugar × 0.6).

As an example of the composition of a Vin Santo produced under a specific DOC rule (*Colli Piacentini* DOC), Table 3.7 includes a summary of data published by Barbieri (2003).

Therefore, the data reported in these past few years, compared with those reported by Tachis (1988), show that, contrary to the past, when the dry style predominated, the slightly sweet style, with a residual sugar between 50 and 100 g L^{-1}, is prefered. Indeed, these data reflect the current opinions of experts for future trends in consumption; their estimates are toward the slightly sweet and sweet styles (*amabile* and *dolce*) of Vin Santo.

For the richness of the volatile compounds, as would be expected for a wine with oxidative aging, the ethyl acetate in all Vin Santo is generally well represented (mean content, about 250 mg L^{-1}). Acetoin is sometimes high (up to 10 mg L^{-1}), while the acetaldehyde content is almost always

TABLE 3.7 Composition of Vigoleno Vin Santo (*Colli Piacentini* DOC) (from Barbieri, 2003)

	Min	Max
Residual sugar (g L^{-1})	80	160
Actual alcohol (%, v/v)	13	18
Total alcohol[a] (%, v/v)	21	25
Total acidity (g L^{-1} tartaric acid)	5.0	6.5
Volatile acidity (g L^{-1} acetic acid)	0.75	1.2
Glycerol (g L^{-1})	>10	

[a] Sum of actual alcohol and potential alcohol (residual sugar × 0.6).

around 100 mg L^{-1} or less. As an average, the contents of methanol and amyl alcohol are generally similar to normal vinifications. In Vin Santo, the ethyl esters (with the exclusion of ethyl lactate), diethyl succinate and diethyl malate, are generally present at low levels, as are acetate esters. The contents of low- and medium-chain fatty acids (C6–C12) are largely variable, but generally low. Instead, there are almost always reasonable levels of butyro-γ-lactone.

As an example, Table 3.8 gives the range of variation and the mean contents of the volatile compounds of some Vin Santo wines on the market (Bucelli *et al.*, 1998), while Table 3.9 gives analogous data derived from industrial trials inoculated with different *Saccharomyces* strains (Berti, 2007).

The different styles of Vin Santo are characterized by particularly complex and unique organoleptic profiles, which arise from the different grapes used and from the particular wine-making process. Although Vin Santo is considered a typical ''oxidative aging'' wine because of the production process. The oxidized character that is linked to the presence of acetaldehyde is however not generally perceived in this wine.

About 25% of commercialized Vin Santo is golden yellow in color, while the larger part of these wines (more than 60%) are yellow amber, with the rest as dark amber.

Compared to most white and red wines, Vin Santo wines, and especially the slightly sweet and sweet styles, are characterized primarily by their flavor and taste, rather than their aroma. Accordingly, in addition to sweetness and acidity, the most used descriptors to evaluate Vin Santo in relation to its perception in the mouth are alcoholicity (warm sensation), texture, viscosity, and overall taste persistence. Among the flavor descriptors, those relating to caramelization (like flavors of honey, milk-honey candy, molasses, caramel) are the most used, as these are more suitable to describe the different Vin Santo. It is estimated that these descriptors

TABLE 3.8 Volatiles compounds in Tuscany Vin Santo (data elaborated from Bucelli *et al.*, 1998)

	Min	Max	Mean
Acetaldehyde (mg L^{-1})	79	111	98
Ethyl acetate (mg L^{-1})	144	352	246
Methanol (mg L^{-1})	32	67	48
1-Propanol (mg L^{-1})	18	34	25
2-Methyl-1-propanol (mg L^{-1})	38	63	51
2-Methyl-2-butanol (mg L^{-1})	34	60	46
3-Methyl-1-butanol (mg L^{-1})	140	228	190
Ethyl lactate (mg L^{-1})	12	370	123
Ethyl butyrate (μg L^{-1})	41	499	196
Ethyl hexanoate (μg L^{-1})	195	452	335
Ethyl octanoate (μg L^{-1})	297	861	456
Ethyl decanoate (μg L^{-1})	25	319	98
Ethyl 3-hydroxybutyrate (μg L^{-1})	122	805	392
Diethyl succinate (μg L^{-1})	19,129	49,134	23,533
Isoamyl acetate (μg L^{-1})	175	414	228
Hexyl acetate (μg L^{-1})	13	197	61
2-Phenylethyl-acetate (μg L^{-1})	23	412	197
Butyric acid (μg L^{-1})	217	1499	745
Isobutyric acid (μg L^{-1})	611	1056	874
3-Methyl-butanoic acid (μg L^{-1})	498	2504	1775
Hexanoic acid (μg L^{-1})	1830	3205	2524
Octanoic acid (μg L^{-1})	1578	4992	3962
Decanoic acid (μg L^{-1})	401	3246	1526
Butyro-γ-lactone (μg L^{-1})	4094	31,249	18,739
Hexanol (μg L^{-1})	995	2488	1810
trans-3-Hexenol (μg L^{-1})	10	55	21
cis-3-Hexenol (μg L^{-1})	41	129	81
3-Ethoxypropanol (μg L^{-1})	81	933	412
3-Methyl-thio-propanol (μg L^{-1})	161	765	385
2-Phenyl ethanol (μg L^{-1})	20,904	48,242	32,032
Acetoin (μg L^{-1})	497	11,788	4850
Benzaldehyde (μg L^{-1})	173	617	450
Benzyl alcohol (μg L^{-1})	15	244	123

account for as much as 40–50% of the total flavors in Vin Santo (Fig. 3.3). The other important descriptors are those that relate to the perception of dried fruit (prunes, sultana grapes, walnut), and to the perception of

TABLE 3.9 Volatiles compounds in inoculated Vin Santo wine (data elaborated from Berti, 2007)

	Min	Max	Mean
Acetaldehyde (mg L^{-1})	36	74	52
Acetoin (μg L^{-1})	800	4800	2800
Ethyl acetate (mg L^{-1})	147	307	215
1-Propanol (mg L^{-1})	23	68	41
Isobutanol (mg L^{-1})	14	141	25
2-Methyl-butanol (mg L^{-1})	16	22	19
3-Methyl-butanol (mg L^{-1})	80	113	92
Ethyl lactate (mg L^{-1})	99	350	197
Diethyl succinate (μg L^{-1})	1069	4253	1856
Octanoic acid (μg L^{-1})	93	188	133
Total higher alcohols (mg L^{-1})	139	305	190
Total ethyl esters (μg L^{-1})	76	150	112
Total acetate esters (μg L^{-1})	37	223	83

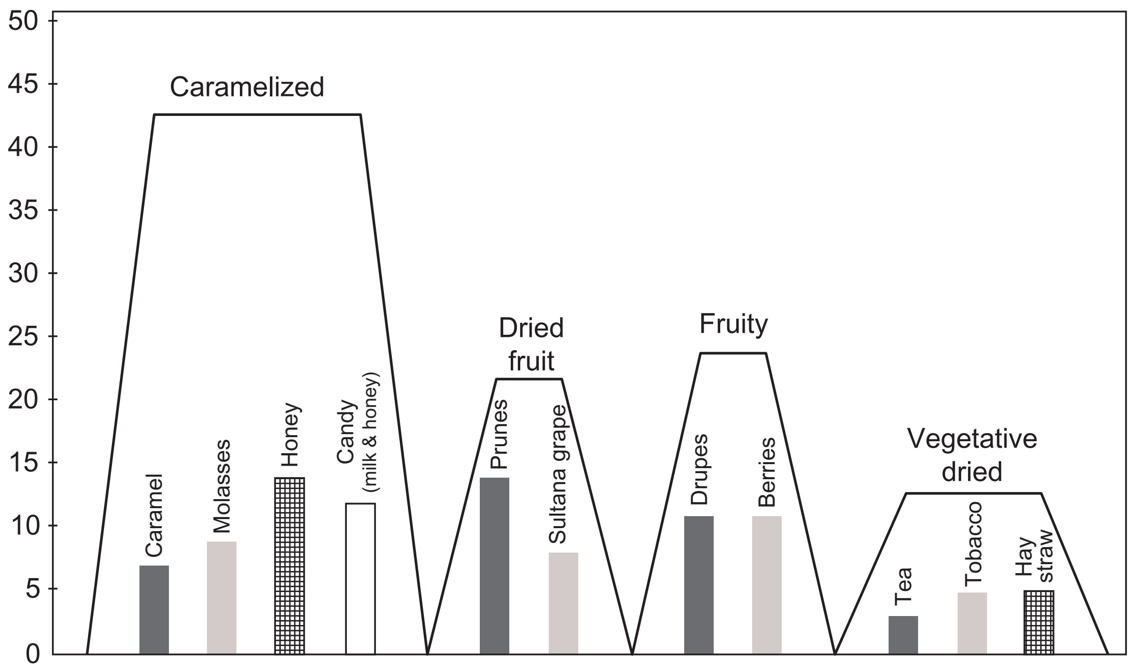

FIGURE 3.3 Frequency (%) of flavor and aroma descriptors in Tuscany Vin Santo. (elaborated from Bucelli *et al.*, 1998)

fruity (drupes, berries), while tobacco and hay/tea are used as descriptors of the perceived dried vegetative aspects, this last generally accounting for 10–15% of the total Vin Santo flavor.

IV. PRODUCTION RULES: ITALIAN AND EUROPEAN UNION REGULATIONS

Following the appreciation of consumers for this type of dessert wine from the middle of last century, to satisfy the increasing demand some low quality Vin Santo-like products began to be available on the market. Many of these products were made by the addition of both alcohol and caramel, and even artificial flavors, to partially fermented grape juice or to white wine, thus obtaining ''special wines'' and/or ''fortified wines.'' Therefore, as a consequence, to combat consumer fraud and unfair competition against the manufacturers of traditional Vin Santo, it became necessary to set up specific public regulations for Vin Santo production. Over the years, Italy has thus applied the protection Denomination of Controlled Origin (DOC) to Vin Santo production, also indicated as *quality wines produced in specific regions* (Vqprd). Accordingly, to be commercialized, each Vin Santo has to conform to the composition and production rules that have been defined by the relevant specific regulations.

Through these designations, over recent years this Italian national regulatory protection has been recognized and harmonized with that of the European Union. From August 2009, the new general classification for wines produced in the European Union became mandatory, as: ''Laying down certain detailed rules for the implementation of Council Regulation (EC) N° 479/2008 as regards protected designations of origin and geographical indications, traditional terms, labeling and presentation of certain wine sector products'' (Reg. EU 607/2009). This regulation encodes the classification system of wine products according to: PDO, Protected Designation of Origin (Italian: DOP, *Denominazione di Origine Protetta*); PGI, Protected Geographical Indication (Italian: IGP, *Indicazione Geografica Protetta*); and traditional terms (like Vin Santo) for wines.

Accordingly, under new EU legislation, all wines produced within the EU are classified as:

- Wines without a designation of origin: current wines (table wines), and wines with an indication of the grape variety and the vintage (varietal wines).
- Wines with a denomination of origin: PDO wines and PGI wines.

Basically, in this last context, the high-quality Italian wines (DOC and DOCG) become recognized as PDO wines, while those typical regional wines produced in restricted areas of Italy (IGT: *Indicazione Geografica Territoriale*) wines become recognized as PGI wines. However, as wine consumers are accustomed to the old signs of DOC/DOCG and IGT, the law permits winemakers to leave this information on the label.

According to the present EU rules of wine classification, only wines complying with the specific DOC/DOP rules (see Table 3.4, above) can be labeled as ''Vin Santo,'' while those wines that are produced by alcohol addition to partially fermented wines or to base-wine must be labeled as Vin Santo ''*vino liquoroso*'' or ''v. I.'' (fortified wine).

V. PRODUCTION AND MARKETING

The production of Vin Santo over the years has become an increasingly specialized market, which is still characterized by both low production and few producers. Although sales of Vin Santo are not quantitatively comparable to those of the majority of wines, production of Vin Santo has increased significantly over the past decade, following the general increase in demand for sweet wines. From market surveys and from data from the major wineries, it has been estimated that in the period 2000–2005 the demand for sweet wines increased by 20% (Scienza, 2006). The demand to date has remained high, and market analysts expect a further medium term increase especially for the more specific productions. As a result of this trend, over the past few years, many wineries have decided to use this product as a showcase for the company, and thus to invest in Vin Santo (Misuri, 2006).

However, as a result of the overall low-production of Vin Santo and its split into different denominations in wine growing areas of central and northern Italy, it is very difficult to find complete information on the production of this wine through the years. Moreover, in the official statistics of wine import and export, Vin Santo and other *passito* wines are not counted separately, but instead together within the class of all other high-quality wines (Vqprd and Vlqprd).

Although it can be very complicated and time consuming, it is however possible to trace the actual figures of Vin Santo, that have been produced under each DOC, through the official registrations of the ''production statements'' presented every year by each winery that produces Vin Santo to the specific Regional Agency of each Italian administrative region.

Thus, even though the official overall data on Vin Santo are lacking, it is however estimated that to date, the production for Tuscany far outweighs that for the rest of Italy, as it represents almost all of the commercial production of Vin Santo.

Considering the Vin Santo produced inside all of the different Tuscany denominations, 5–6 years ago there was a doubling in production, which is currently maintained at just below 400,000 L per year (Fig. 3.4).

Similarly, the production of the rare *occhio di pernice* style has increased over these years, with a share that has grown from some 5% to 8% with

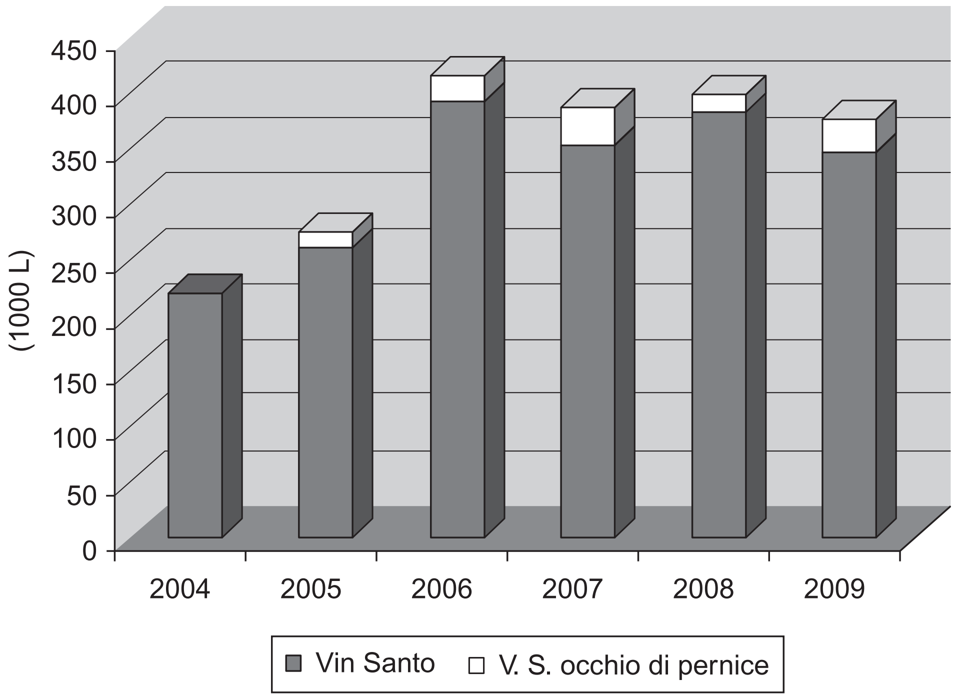

FIGURE 3.4 Production of Vin Santo in Tuscany under the different DOC rules over the past 6 years. (from ARTEA, 2010)

respect to the total production of Vin Santo. As the production data show (Table 3.10), only in some Tuscany areas with DOC has the production of Vin Santo been fairly constant over the years. For the greater part of the DOC areas instead, the production normally fluctuates, due to great difficulties (with the traditional processes) in reaching every year the standards imposed by the respective DOC rules.

Table 3.11 summarizes the production data for Vin Santo di Vigoleno, produced inside a specific DOC-rule (DOC: ''Colli Piacentini'').

In a recent survey carried out by questionnaire (Fig. 3.5), Panella (2006) reported that among the Tuscany wineries Vin Santo-making investigated, almost half those produced an average of 600–1000 L of this wine per year, while 25% produced an average of 1000–4000 L. Only 10% of the wineries produced more than 4000 L, while about 19% of the wineries produced quantities lower than 500 L, which was just enough for their own use.

The greater part (>75%) of the Tuscan Vin Santo was produced in the slightly sweet or sweet stile (38% and 39%, respectively), while the dry style (with 10–50 g L^{-1} residual sugar) accounted for only 23%. These data related to the production of all types of Vin Santo, including the *occhio di pernice* style.

From market surveys and data from the major wineries, it has been estimated that Tuscany is still the main market for this product. Although specific official data are lacking, according to many sales managers and

TABLE 3.10 Tuscany production of Vin Santo under the different DOC regulations over the last 6 years (data from ARTEA, 2010)

	Production (L)					
Official wine denomination (DOC)	2004	2005	2006	2007	2008	2009
Vin Santo style						
Bianco della Valdinievole Vin Santo				100		
Bianco dell'Empolese Vin Santo				9175	10,230	15,700
Bianco Pisano di San Torpe' Vin Santo		1950	4440	1850	1000	2275
Capalbio Vin Santo						
Carmignano Vin Santo		4067	24,529	10,079	8176	8435
Colli dell'Etruria Centrale Vin Santo		10,898	11,684	7858	6294	4630
Colline Lucchesi Vin Santo						245
Cortona Vin Santo			95	1195	2066	1620
Elba Vin Santo					166	173
Montecarlo Vin Santo				1520	570	720
Monteregio di Massa Marittima Vin Santo		185	550	1135		629
Montescudaio Vin Santo				600		
Orcia Vin Santo		1545	3111	6790	5680	5487
San Gimignano Vin Santo		10,480	12,680	8605	8494	3839
Sant'Antimo Vin Santo		1300	2938	6298	4729	7090
Val d'arbia Vin Santo					1704	
Valdichiana Vin Santo		700	2783	3475	40,100	3800
Vin Santo del Chianti Classico	186,900	74,527	81,051	100,700	84,077	79,609
Vin Santo del Chianti	4100	137,660	193,027	180,287	195,629	179,274
Vin Santo del Chianti Colli Aretini					400	
Vin Santo del Chianti Colli Fiorentini		450	3200	2930	2523	980
Vin Santo del Chianti Colli Senesi		7430	1050	4342	400	8990

(*continued*)

TABLE 3.10 (*continued*)

	Production (L)					
Official wine denomination (DOC)	2004	2005	2006	2007	2008	2009
Vin Santo del Chianti Montalbano		1430	700	455	455	355
Vin Santo del Chianti Montespertoli		1400	3100			
Vin Santo del Chianti Rufina			8425	2357	5092	1112
Vin Santo Montepulciano	28,300	6873	37,740	3320	4135	21,000
Vin Santo Occhio di Pernice style						
Bolgheri Vin Santo Occhio di Pernice						
Carmignano Vin Santo Occhio di Pernice		2000			760	850
Colli dell'Etruria Centrale Vin Santo Occhio di Pernice					450	
Cortona Vin Santo Occhio di Pernice						175
Elba Vin Santo Occhio di Pernice					330	250
Monteregio di Massa Marittima Vin Santo Occhio di Pernice		220				480
San Gimignano Vin Santo Occhio di Pernice				520		385
Sant'Antimo Vin Santo Occhio di Pernice				1500		
Vin Santo del Chianti Classico Occhio di Pernice			6000	18,665	1116	2433
Vin Santo del Chianti Occhio di Pernice		5575	17,150	13,508	12,701	24,843
Vin Santo del Chianti Occhio di Pernice Colli Fiorentini			1200			
Vin Santo del Chianti Occhio di Pernice Montespertoli			350			
Vin Santo del Chianti Occhio di Pernice Colli Senesi		1000				
Vin Santo del Chianti Occhio di Pernice Rufina		4345			8	105
Vin Santo Montepulciano Occhio di Pernice		140				1300

TABLE 3.11 Production data for Vin Santo of Vigoleno from 1996 to 2009 (from: Consorzio di Tutela Vini DOC, Colli Piacentini, 2010)

	Vineries (N°)	Ha	Grape (q Ha^{-1})	Vin Santo (L)
1996	2	0.42	45.2	570
1997	2	0.42	45.2	570
1998	3	0.52	48.1	750
1999	4	1.05	32.4	1000
2000	6	1.18	35.6	1300
2001	6	1.18	42.4	1500
2002	4	1.12	46.7	1568
2003	6	1.61	50.3	2428
2004	8	1.69	44.7	2269
2005	6	1.43	36.4	1600
2006	6	1.75	26.9	1400
2007	6	1.97	22.3	1300
2008	8	2.55	23.5	1800
2009	8	1.96	30.9	1820

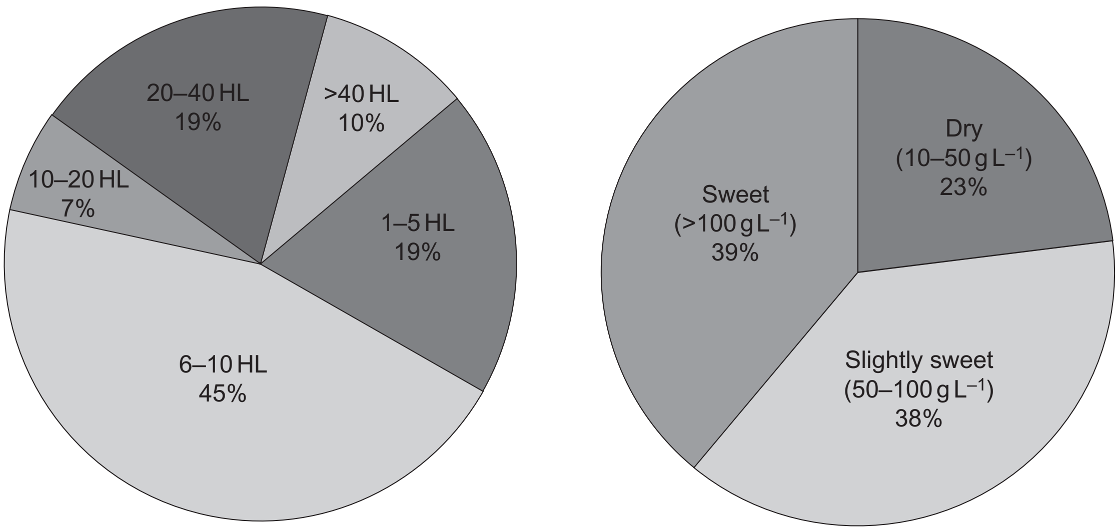

FIGURE 3.5 Production (left) and style (right) of Tuscany Vin Santo. (elaborated from Panella, 2006)

marketing managers, over the past few years around 80% of the Vin Santo has been sold in Italy, of which about 80% has been sold in Tuscany (Misuri, 2006). The main markets for Vin Santo export remain the USA, Britain, and Germany.

In Italy, and especially in Tuscany, the sales are very seasonal, as they are related to holidays (Easter and Christmas mainly) and to the tourist season, while sales to foreign countries are generally scheduled at the beginning of the year, by agreements between the wineries and their distributors.

The Vin Santo produced as DOC is mostly sold in 500 mL bottles, or as 375 mL for the more expensive ones. The cheaper Vin Santo and the sweet Vin Santo-like wines (fortified wines) are instead generally sold in 750 mL bottles. In terms of the market positioning, the products are sold across a wide range of prices. At present, most of the Vin Santo in Italy is priced between €10 and €50 per bottle (15–150 €/L), even if some are much more expensive. On the basis of statements from the Tuscan producers regarding the medium positioning of their products on the market, Panella (2006) reported the data shown in Fig. 3.6A. In the same year, Misuri (2006) investigated the sale of Vin Santo in the city of Florence, and obtained different findings (Fig. 3.6B), probably as a consequence of the different consumer targets, as this latter investigation took place directly at the point of sale, in the specialized wine shops.

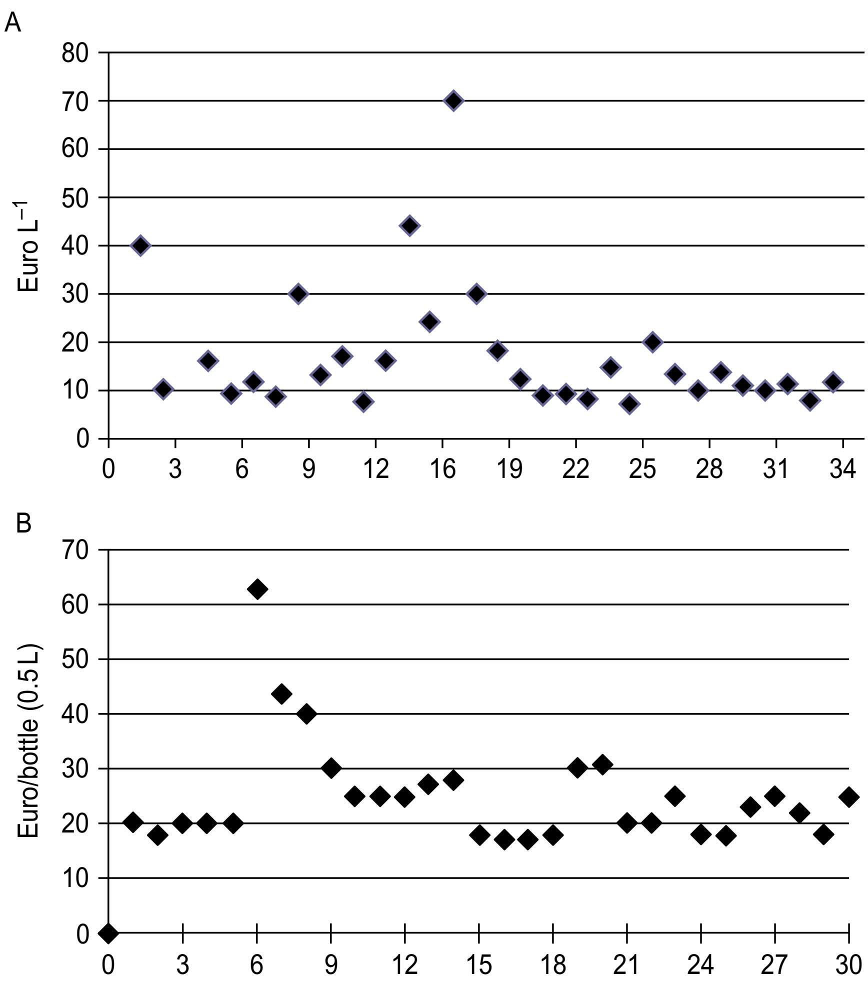

FIGURE 3.6 Positioning (cost) of Vin Santo on the market. (elaborated from (A) Panella, 2006 and (B) Misuri, 2006)

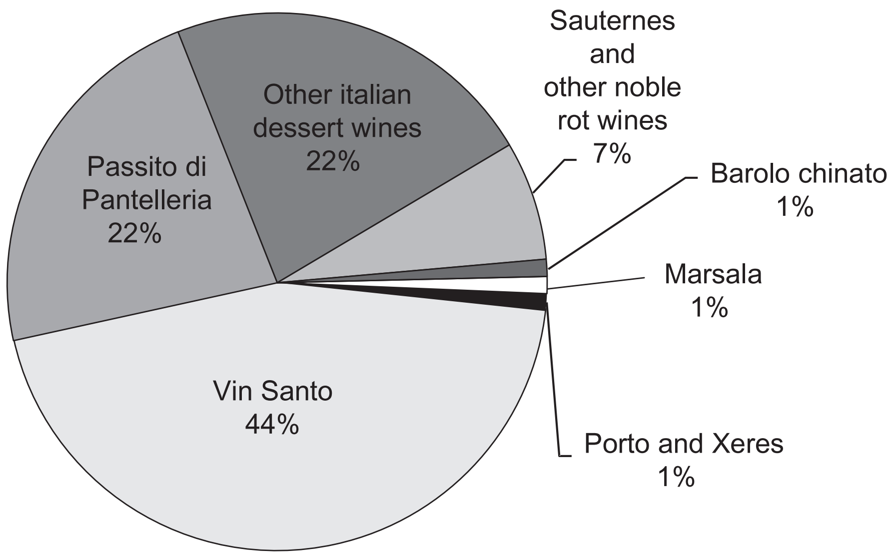

FIGURE 3.7 The dessert wine demand defined for Florence. (elaborated from Meucci, 2008)

In a recent thorough investigation focused on dessert wine demand in the Florentine areas, Meucci (2008) reported that these consumers showed a clear preference (44%) for Vin Santo (Fig. 3.7). The preference of the remaining consumers was mainly for Passito di Pantelleria and for other Italian dessert wines (44% in all). Only a small share of consumers (around 7%) bought dessert wines from the noble rot, while the remaining 3% purchased from among all of the other Italian and non-Italian dessert wines.

VI. THE MAKING VIN SANTO

All of the production of Vin Santo in Italy follows the general scheme shown in Fig. 3.8, with the main differences relating to the must composition (grape varieties and grape drying) and to the fermentation and aging conditions. Although Italy is the country with the World's greatest tradition for sweet wine production (Fregoni, 2006), most of the steps of the Vin Santo making process are still linked to old local traditions, and therefore, scientific-technical approaches are rarely used.

A. Grape varieties

Vin Santo is made by starting with the choice of the best grapes (*scelti*) of the white varieties that are grown in each zone. As a ''sweet'' wine that is little characterized by terpene aromas, the making of Vin Santo can use non-aromatic or semi-aromatic grape varieties. Not all of the ''non-varietal'' grapes, however, are suitable for producing Vin Santo,

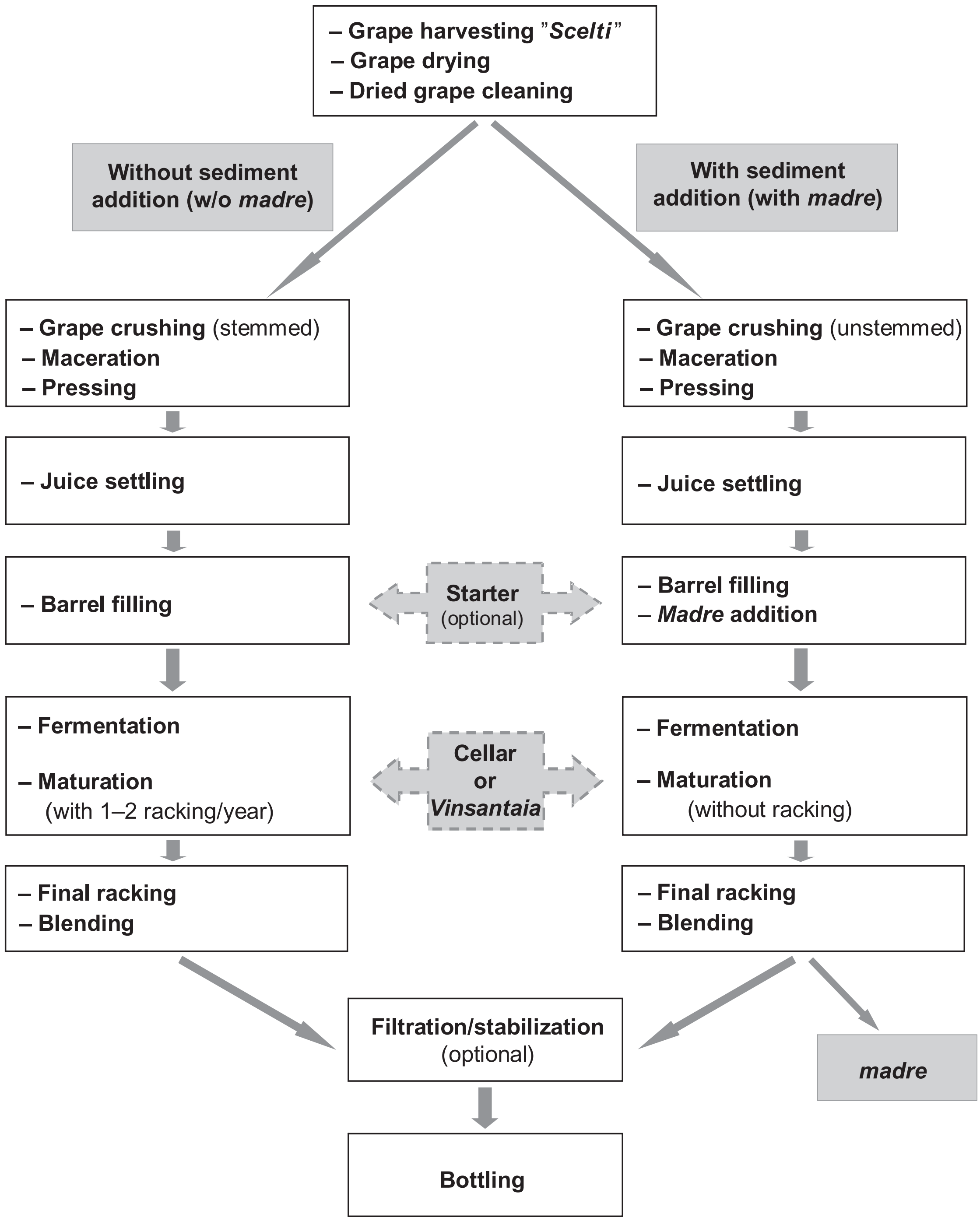

FIGURE 3.8 Flow diagram for Vin Santo production.

and often a grape variety can be suitable for the making of good Vin Santo in one place, but not in another.

Similarly, as for the production of other *passito* wines from partially dried grapes, such as Recioto, Albana passito, and Picolit (which we refer to as ‘‘non-aromatic *passito* wines’’), generally the grape varieties and clones used should be those with a thicker skin and more open clustered small berries, as these are best for drying under mild conditions, with less likelihood of excessive danger of rot growing. Grapes can therefore also be used from vines that are growing in poor soil that is airy and sunny, with limited foliage, and with the clusters not too close to the ground. In Tuscany, the grapes that are mainly used for Vin Santo are Trebbiano, Canaiolo, Chardonnay, Grechetto, S. Colombano, Pinot bianco, Pinot grigio, and Malvasia bianca del Chianti. In other areas of Italy, the grapes used for Vin Santo production are the varieties typical of the area, as indicated in Table 3.4. For example, for the production of Vin Santo Trentino, the Nosiola grape variety is mainly used.

B. Grape drying

1. Grape-drying techniques

Depending on the production rules and the local traditions, different techniques are used to remove the water from the grapes that are used for the production of *passito* wines (see above Table 3.2).

Generally, these techniques are based on an over-ripening process for grapes on the vines (e.g., late harvest, ice wines) or on off-the-vine processes. For the latter, the grapes can be exposed to the sun, as in the south of Italy for aromatic *passiti* (such as Passito di Pantelleria) that are produced from the aromatic grape varieties (e.g., Moscato, Aleatico), or they can be dehydrated in a ventilated room under environmental conditions, as is typical for the *passito* wines of central and northern of Italy (e.g., Vin Santo, Caluso, Sciachetrà, Picolit, Recioto, Amarone). Forced ventilation or complete air thermo-hydro conditioning throughout the drying period is sometimes used for the production of cheap sweet wines. However, despite the possible benefits arising from the use of this fast dehydration technique (reduce labor costs, rapid high sugar concentrations, minimizing of losses to mold), the grape harvesting and drying need to be as mild a process as possible, in order to respect the local traditions and to obtain high-quality wines. The best rules for Vin Santo wine production, for instance, require the hand harvesting of the grapes from the healthier bunches, and slow drying conditions close to room temperature. Traditionally, for the production of Vin Santo, the grape drying takes place on special mats, with the grapes spread as a single layer and sufficiently spaced for the air to circulate. This takes place in a special room, known as the *fruttaio*, which is exposed to natural ventilation at ambient temperature and humidity. Here, it can take up to 3–4 months to concentrate the sugar content to 26–30% (w/v) and above, with a weight loss of the grapes of up to 35–40%. To facilitate water loss from the grapes and to reduce the risk of molds developing, the ventilation can be increased with fans during the early period of the drying (the first few days).

Accordingly, the techniques applied for grape drying are still based on empirical practices, and often the controls applied consist only in monitoring the evolution of the sugar concentration and in the cleaning of the moldy clusters. Indeed, at the beginning of the dehydration process, when both the relative humidity and the temperature are high, *Botrytis cinerea* can grow on grapes, developing as ''gray rot'' and resulting in low yields and low-quality wines (Francioli *et al.*, 1999, Zironi *et al.*, 1983). To control this gray mold development, it is common practice to use SO_2 or sulfite salts. However, while *B. cinerea* can develop also as ''noble rot,'' with positive effects on the wines (e.g., increased sugar content, lower acidity, reduction in total nitrogen) (Corte *et al.*, 2001), its contribution to the typical Vin Santo aroma is negligible.

2. Grape metabolism in the drying process

Grape dehydration is not only a simple process of concentration of the sugars due to water loss from the berries. Various studies have reported that the water loss during the dehydration process results in a stress event that can induce significant changes in the metabolism of fruits and vegetables, such as a gradual degradation of the cell wall, increased respiration, activation of ethylene production, increased abscisic acid content, and accumulation of proline (Costantini *et al.*, 2006; Hsiao, 1973; Kays, 1997).

3. Factors influencing the grape-drying process

The drying process of the grapes depends principally on the air conditions (e.g., temperature, relative humidity, natural air flow) and the grape characteristics (e.g., surface area/volume ratio, skin thickness, cuticle waxes, ripening degree). For many years, different studies have highlighted the influence of temperature and relative humidity on the rate of the respiration process, and they have shown how the main organic compounds undergo a series of biological and chemical changes (Corte *et al.*, 2001; Ferrè, 1926; Ruffner *et al.*, 1976; Zironi and Ferrarini, 1987). Accordingly, it has been seen that the maximum respiration process occurs at 35 °C, while a temperature higher than 60 °C can result in cell death and a decline in the biological activities of the berries. Different acid and sugar concentrations can therefore arise as a function of the different temperatures used. In particular, temperatures higher than 50 °C result in improved sugar and acidity, temperatures between 45 and 50 °C promote increased sugar but not acidity, temperatures between 40 and 45 °C increase the sugar and decrease the acidity, and temperatures between 35 °C and 40 °C mainly result in an acidity decrease. Although following the water loss there is a percentage enrichment in the sugar, there is at the same time a decrease in the net weight of sugar. This is due to active cellular respiration, which is particularly high around 35 °C, and which results in the sugar consumption. Moreover, in a study conducted on Recioto and Amarone wines, Usseglio-Tomasset *et al.* (1980) observed a lowering of the glucose/fructose ratio, which was probably due to the enzymatic transformation of glucose to fructose, or to the metabolism of glucose through the pentose cycle.

Regarding organic acids metabolism, Amati *et al.* (1983) reported that malic acid is consumed in both natural and conditioned systems, although it was more intense in the latter. This malic acid decrease is probably due to the respiration processes and/or to malic acid conversion into sugar (gluconeogenesis). In contrast, tartaric acid decreases slightly, and no differences were seen between the two drying systems.

4. The drying process and aroma compounds

While most of the studies carried out to date have focused on the evolution of the primary compounds, such as the sugar and acid components, little data exist for the other quality characteristics, and in particular, for aroma. However, most of these studies have been conducted on the aromatic varieties. For instance, some experimental studies conducted on different aromatic cultivars under different conditions mainly reported the evolution of terpene compounds during the dehydration process. Accordingly, it has been showed that after the grape harvest, activation or inhibition of the metabolism involved in the biosynthesis of the aroma compounds is strictly dependent on the grape dehydration technique.

In a study conducted on Zibibbo grapes, Di Stefano *et al.* (1995) compared three different drying systems, with the grapes exposed to the sun, overripened on the plant, and subjected to a fast drying technique (50–60 °C for 3 days). In this study, it was evident that the evolution of the terpene compounds depended on the drying system used, and independently of this, the decrease in the sugar content and in the free and bound terpene compounds was directly correlated to the drying rate. In particular, it was noted that free linalool, the most important of the aromatic compounds, decrease rapidly from the beginning of the drying process, while the contents of all of the free and glycosylated terpene compounds underwent significant decreases throughout the process of drying under the sun. Moreover, terpene compounds do not undergo structural changes during this process, except for partial hydrolysis during their diffusion from the grape skin to the juice. The greatest loss of terpene compounds occurred during the drying under the sun or with the increased temperature in the fast drying. Considering these changes in the terpene compounds as a parameter for comparisons, the best drying conditions among those considered were those on the plant.

A similar study carried out on Malvasia delle Lipari grapes (Corte *et al.* 2001) showed that in the relevant *passiti* wine the content of glycosylated terpenes was extremely high, particularly in a sample obtained from grapes dried in an artificial dehydration system; the wine obtained from the use of this artificial dehydration showed a glycosylated terpene composition close to that of the grape variety. In contrast, wines obtained from grapes dried under the sun showed an aroma characterized by both varietal notes and oxidative notes.

In studying the evolution of terpene compounds during the drying process for the Muscat Bianco variety, Eberle *et al.* (2007) noted that independent of the mode of drying (on the vine with a late harvest, or in an artificially conditioned cell at low temperatures and humidity), the free and bound terpene compounds were degraded, with a consequent decrease in their levels. Moreover, the free terpene compounds were lower in juice obtained from grapes dehydrated on the vine, as compared to those ones from grapes dehydrated in an artificially conditioned cell, and *vice versa* for the glycosylated terpenes.

To better understand the metabolic changes that can occur during the dehydration process, and to identify the determining parameters for these changes, some studies were conducted on the Gewürztraminer grape variety (Chkaiban *et al.*, 2007), and on Trebbiano, Malvasia, and Sangiovese grapes (Bellincontro *et al.*, 2002, 2004; Costantini *et al.*, 2006). These studies compared the results of grape drying in a window-ventilated room (uncontrolled environmental conditions) and in a thermo-conditioned tunnel (controlled temperature and humidity). The results showed that controlled conditions versus uncontrolled conditions provided a more uniform dehydration, and showed slower stress to the berries, giving a higher quality product without a loss of berries. In particular, Bellincontro *et al.* (2004) compared the quality characteristics and volatile compounds in the juice of grapes dehydrated at fast and slow rates. In Malvasia and Sangiovese juice, it was seen that fast grape dehydration resulted in an increase not only in sugar but also in esters and higher alcohols content. In the tunnel-treated Sangiovese grape juice, higher contents of phenols and anthocyanins were also *found*. In contrast, dried Trebbiano grape juice was not affected by these different rates of grape dehydration.

Costantini *et al*. (2006) and Chkaiban *et al*. (2007) also focussed their attention on the roles of enzymes such as lipoxygenase (LOX) and alcohol dehydrogenase (ADH) during the dehydration process of Malvasia and Gewürztraminer grape varieties. As is known, the LOX enzyme acts on membrane lipids, so as to degrade cell membranes and to increase ion leakage and water loss (Maalekuu *et al*., 2006), while ADH, which catalyzes both the reduction of acetaldehyde to alcohol and the oxidation of the alcohol to acetaldehyde, was essential for understanding the activation of a fermentation process in cells during grape drying.

When working with Malvasia grapes that were dried under regulated tunnel-treatment conditions (15 °C, 40% relative humidity, 1.5 m s^{-1} air flow), Costantini *et al*. (2006) showed that cells can undergo an initial water stress response, with the accumulation of abscisic acid, proline and

LOX, until they reached a weight loss of 10–12%. These changes dramatically increased when the weight loss surpassed 19%, at which point there was a significant increase in ADH. This metabolism led to the initial formation of C6 compounds, ethanol and acetaldehyde, and then a decrease in the acetaldehyde was seen in the next step, following the production of ethyl acetate. The same study showed an increase in respiration at a weight loss of 10%, with a maximum at around 22% weight loss. Other studies found aerobic metabolism changed to anaerobic metabolism at 10–15% weight loss: under these conditions, glucose and malic acid were transformed into ethanol and CO_2 (Romieu *et al*., 1992).

Working with Gewürztraminer grapes, Chkaiban *et al*. (2007) found that in the berries dehydrated under regulated tunnel-treatment conditions (17 °C, 40% relative humidity, 1.5 m s^{-1} air flow), water stress was delayed, while under the traditional uncontrolled environmental conditions, it was accelerated, even at a lesser extent of water loss. These findings suggest that each grape variety has a different response time, although similar ways of responding to water stress, with increases in LOX and ADH activities, and relative changes in the volatile compounds.

The evolution of other marker compounds of water stress, such as carotenoids, has also been considered. As is known, carotenoids have an important role in the protection of the cell against stress conditions, and it has been reported that they decrease during grape ripening (Oliveira *et al*., 2003; Razungles *et al*., 1996). Chkaiban *et al*. (2007) suggested that in white grapes, oxidation of the carotenoids during the dehydration process might be an important mechanism for the formation of specific volatiles. Degradation of the carotenoids led to the production of norisoprenoids, which contributed to the wine as pleasant aroma compounds (Oliveira *et al*., 2003). With Gewürztraminer berries dehydrated under regulated tunnel-treatment conditions, Chkaiban *et al*. (2007) found that the carotenoids declined significantly, and then increased slightly toward the end of the experiment, in the same way as in the control grapes that were dried traditionally in a window-ventilated room under uncontrolled environmental conditions. Under these last conditions, however, a more rapid decline was seen.

C. Pressing and barrel filling

After drying, the healthy grape berries are separated from those that show rot, or that have been damaged by insects, and then they are pressed. The pressing of dried grapes is a very delicate step in the Vin Santo production, because of the risk of increasing the incorporation of suspended solids that decrease juice quality. Despite this, vertical or horizontal presses are still used as they can help to extract the greatest possible amounts of juice from dehydrated grapes. However, to obtain high-quality juice, many winemakers actually use pneumatic presses.

The must is then left to settle for 3–4 days at temperature below 8–10 °C. Indeed, contact with the sediment can cause the future Vinsanto to show unwanted aroma deviations and color. In this context, more attention needs to be paid to the settling of the must from botrytised grapes. From the sugars, *B. cinerea* can produce polysaccharides that can muddy the wine and have inhibitory actions on the metabolism of the yeast, and can therefore contribute to the slowing of fermentation and to the increase acetic acid and glycerol production by the yeast (Tachis, 2003).

The decanted juice is fermented in traditional wooden barrels, known as ''caratelli,'' which holding between 50 and 200 L. Many winemakers consider these small barrels a factor in wine quality. These might be new, or more frequently, they will be used barrels (also 20 or more years old) that are often from previous productions of Vin Santo. Today, used barriques (capacity, 225 L) are also used. The woods used are chestnut, cherry, and oak, in particular. The current opinion suggests the sensory characteristics brought to the wine, nontoasted oak is the best wood also for Vin Santo production. Moreover, because the fermentation often takes place in closed vessels, barrels of traditional thickness (3 cm or more) help to avoid the risk of rupture during fermentation.

D. Alcoholic fermentation

After the pressing of the dried grapes, the alcoholic fermentation follows, along with the biological aging in barrels (caratelli) at ambient temperatures for 2 or more years in a traditional room, known as *vinsantaia*.

As for grape dehydration, the management of alcoholic fermentation is still linked to traditional practices, which provide very poor control of the fermentation parameters, such as microbial population and temperature.

To date, although many studies have been conducted on microbial population dynamics with different grape varieties and fermentation conditions, very few of these have been strictly related to Vin Santo. Despite this, various studies regarding the alcoholic fermentation of other Italian *passito* wines, which have similar production characteristics to those of Vin Santo, have been produced, contributing to the understanding of some important microbial aspects of this particular production process.

1. Influence of grape drying on microbial population dynamics in alcoholic fermentation

The grape berry microflora can vary according to climate conditions (Parish and Carroll, 1985) and grape variety (Schütz and Gafner, 1993). Similarly, the drying process can result in changes in the microflora on the grape surface, and thus in the microflora involved in the subsequent fermentation phase (Balloni *et al.*, 1988; Caridi and Audino, 1997; Cavagna *et al.*, 2008; Gori, 1989; Lombardo *et al.*, 2007; Nuti *et al.*, 2007; Urso *et al.*, 2008).

Indeed, grapes are a primary source of microorganism, and many studies have shown that natural fermentation starts with those species predominant on grapes at harvest time (Fleet *et al.*, 2002). These can include the apiculate yeasts (*Hanseniaspora uvarum* and *Kloeckera apiculata*), *Metschnikowia, Candida*, *Pichia*, *Rhodotorula*, and *Kluyveromyces*. In contrast, although it is the main wine fermentation yeast, *Saccharomyces* have only rarely been isolated from vineyards (Martini, 1993; Martini *et al.*, 1996; Pretorius, 2000; Sabate *et al.*, 1998), since it is closely associated with the winery environment (Ciani *et al.*, 2004).

Referring strictly to the grape varieties used for Vin Santo production, some Authors (Balloni *et al.*, 1988; Gori, 1989) conducted a study on the evolution of microflora present on the surface of Malvasia and Trebbiano toscano grapes during the dehydration. They observed that lactic acid bacteria increased during the drying of Malvasia (20% after 30 days; 70% after 70 days), while they were not present on the Trebbiano variety. At harvest, the most representative yeast on Malvasia Bianca was *Metschnikowia pulcherrima*, while on Trebbiano toscano, apiculate yeasts dominated (*H. uvarum* and *K. apiculata*). During the natural drying period, there was an overall decrease in the number of yeasts. However, on Malvasia Bianca, *M. pulcherrima* remained the dominant species, followed by *Torulaspora delbrueckii* and *Saccharomyces cerevisiae*. On Trebbiano toscano, apiculate yeasts decreased in favor of *M. pulcherrima*, *T. delbrueckii*, and *S. cerevisiae*.

In studying the microflora composition during the fermentation process of Vin Santo, Lombardo *et al.* (2007) observed that at the beginning of the fermentation there was a high prevalence of apiculate yeasts, while 2–4 months later, *Saccharomyces* sp. dominated. Through five different vintages, 318 yeasts were isolated and identified by phenotypic and molecular analysis. In particular, 13 different species were identified, belonging to the genus *Saccharomyces*, *Pichia*, *Debaryomyces*, *Candida*, *Zygosaccharomyces*, *Hanseniaspora*, *Kloechera*, and *Metschnikowia*.

With the aim of isolating suitable yeasts to be used as a fermentation starter for specific local production, Cavagna *et al.* (2008) evaluated the microflora during the natural drying process of Nosiola grapes, a variety used for the production of Vin Santo Trentino. In particular, they reported that in one of the two vintage monitored, the most represented species were those belonging to *Candida zemplinina*, *Hanseniaspora opuntiae*, *M. pulcherrima*, and in some case, also *Zygosaccharomyces rouxii*. It was noted that when *Z. rouxii* was present on the dried grapes, it also dominated the fermentation process that followed. In contrast, *S. cerevisiae* dominated the fermentation process when it started with *H. opuntiae*.

In the following vintage, *M. pulcherrima*, *H. uvarum*, and *C. stellata* were the prevalent yeasts during the first steps of the dehydrating process, and subsequently, halfway through the dehydrating process, the microflora composition was changing. Depending on the cellar environment, *C. zemplinina* or *M. pulcherrima* were the most represented yeasts. At the end of the dehydration process, osmophile species were especially present, including *H. opuntiae C. zemplinina*, *Z. rouxii and M. pulcherrima*. Also in this case, after the grape pressing, during the alcoholic fermentation they saw a succession of different species: *H. opuntiae* at the beginning, *C. stellata* persistent until the middle of the fermentation, and *S. cerevisiae* was dominant at the end of fermentation.

Other studies conducted on grape cultivars different from those used for Vin Santo production have permitted the evaluation of the microbial changes that take place during drying and the alcoholic fermentation. On Greco bianco and Mantonico bianco, two grape varieties that are used to produce the main Calabrian dessert wines, Caridi and Audino (1997) evaluated the yeast evolution at different ripening and dehydrating times (before harvest, at harvest, and at the end of the withering process). They observed that *Hanseniaspora guilliermondii* was the only yeast present on under-ripe grapes, and in all cases, it was the predominant species. Other yeasts, belonging to *Candida* spp. and *Zygosaccharomyces bailii*, appeared after the partial drying process. Strains of *S. cerevisiae* have also been detected at ripening.

Urso *et al.* (2008) considered the dynamics of the main microbial groups from grape to wine, during production of Picolit; here, they confirmed that most of the isolates from the grape and must belonged to the species of *Metschnikowia*, *Hanseniaspora*, and *Candida* and a smaller quantity to *Pichia*, *Torulaspora*, *Debaryomyces*, *Zygosaccharomyces*, and *Saccharomyces*. Moreover, the most abundant species belonged to *C. zemplinina* and *Hanseniaspora clermontiae/uvarum.*

The type of drying condition can also differently influence the grape microflora composition. In this context, Corte *et al.* (2001) referred to the microflora found in the must soon after the pressing of Malvasia and Zibibbo grape varieties, which were dried differently. The must obtained from sun dried grapes showed amounts of yeasts at least 10-fold greater than that present on the must deriving from the grapes dried in a thermal conditioned system. In this last system, the lower relative humidity determined the healthiest grapes. Moreover, independent of the drying system adopted, *Saccharomyces* yeasts were present on the must obtained from Malvasia and Zibibbo grapes at concentrations of 24–30% and 20–30%, respectively, while non-*Saccharomyces* yeasts were at concentrations of about 50 and 60%, compared the total microbial levels. In particular, on Malvasia, the non-*Saccharomyces* yeasts were represented mainly by *Hanseniaspora guillermondi*, and to a lower extent by *Pichia membranaefaciens* and *M. pulcherrima*. On the Zibibbo varieties, other yeasts belonging to *Candida* and *Zygosaccharomyces* were also seen.

2. Microbial management of alcoholic fermentation

The quantitative presence of the different kinds of yeasts during alcoholic fermentation, is influenced by different parameters, such as fermentation temperature, oxygen concentration, and grape juice composition (Chaney *et al*., 2006; Erten, 2002; Gao and Fleet, 1988; Hansen *et al*., 2001; Heard and Fleet, 1988). A high sugar concentration together with a low temperature definitely makes the beginning of the alcoholic fermentation more difficult, which according to the traditional production processes for the making of Vin Santo occurs under ambient temperatures and humidity. The dramatic variations in the environmental temperatures through the whole fermentation process strongly influence the growth and fermentative abilities of the wine yeasts.

a. Madre *addition* With the aim of providing a good fermentative starter that can better overcome the initial stressing conditions of the alcoholic fermentation, and in agreement with the traditional protocol, just before barrel filling the must is traditionally enriched with 5–10% of the sediment collected from the barrels at the end of the ripening of the previous Vin Santo wine production, known as the *madre.* Indeed, despite there being no scientific evidence to date, this sediment is believed to contain selected yeasts that are well adapted to adverse fermentation conditions, and therefore, they are thought to be able to start the fermentation process easily. However, Domizio *et al.* (2007) reported that *madre* appeared to have no direct role as a microbiological starter in Vin Santo production. Indeed, it was not possible to isolate yeasts belonging to the genus *Saccharomyces* from this substrate using classical isolation methods, either with or without enrichment. Similarly, Casalone and Polsinelli (2002) reported the almost total absence of *Saccharomyces* yeast strains in the *madre*, and therefore, it could not be used for the purpose of adding strains able to start the fermentation process.

Moreover, Domizio *et al.* (2007, 2008) reported that the only strains found on the *madre* after 3 years of aging were those belonging to the genus *Zygosaccharomyces*. Therefore, the *madre* can serve as a source of these kinds of yeasts, and their persistence could be explained by their adaptation to the Vin Santo conditions and their well-known tolerance to high ethanol and sugar concentrations (Fugelsang, 1997). Accordingly, Devetta (2009) found that *Zygosaccharomyces* represented the most active yeasts in a must for Vin Santo.

However, in a successive study, Domizio *et al.* (2008) showed the positive influence of Vin Santo *madre* on yeasts growth and their persistence during fermentation, as well as on the fermentative activities of the wine yeasts. Also the biodiversity of the spontaneous *S. cerevisiae* yeasts was positively influenced. According to Gómez *et al.* (2004), who analyzed the composition of lees from Sherry wines, the sediment can provide a source of lipids that are released following yeast autolysis (Pueyo *et al.*, 2000) and therefore incorporated under anaerobic conditions (Luparia *et al.*, 2004) to modulate the lipid composition of their cell membranes in response to environmental stimuli (Belviso *et al.*, 2004). These exogenous lipids, together with other nutritional factors present in the *madre*, would support mainly the growth of the *S. cerevisiae* strains naturally present in the must and selected in particular environments, such as dried grapes, *fruttaio* and *vinsantaia* (Domizio *et al.*, 2008).

Despite no microbiological role being recognized for this *madre*, as already noted (Domizio *et al.*, 2007; Lencioni *et al.*, 2009; Romani *et al.*, 2009), it can have a strong influence on the sensory attributes of Vin Santo (Fig. 3.9).

b. Fermentation starter Over the past few years, despite the strong traditions linked to the production of most of the Italian *passito* wines, a lot of wineries have started to inoculate the must with the aim of standardizing their process and to obtain wines with valuable and reproducible characteristics. Indeed, the traditional processes, which are carried out with poor control of the process variables, can lead to the production of excellent wines, although their characteristics may vary dramatically from year to year.

Accordingly, with the aim to select *Saccharomyces* strains with suitable characteristics for fermentation of must with such a high sugar concentration, different studies have tested both commercial and indigenous *Saccharomyces* yeast strains isolated along the production chain of this particular niche product. Indeed, these yeasts are the result of natural selective pressure due, in particular, to the high sugar and ethanol concentrations. In addition, the inoculation of the starter strains occur in winter. Thus, at the beginning of the fermentation, the yeasts are subject to low temperatures. Indeed, such stressing conditions may be negative for the dominance of the starter strains that had not been subjected to selective pressure in fermentation processes with similar characteristics (Querol *et al.*, 2003).

This is what occurred to those strains of *S. cerevisiae* selected for traditional vinification processes (whether a commercial starter and not) that have been tested for the production of sweet wines, such as Picolit (Urso *et al.*, 2008) and Vin Santo wine (Domizio *et al.*, 2008); here, they were not able to dominate the relative fermentation process. On the contrary, Unican Sherry yeast, which is normally used for the production

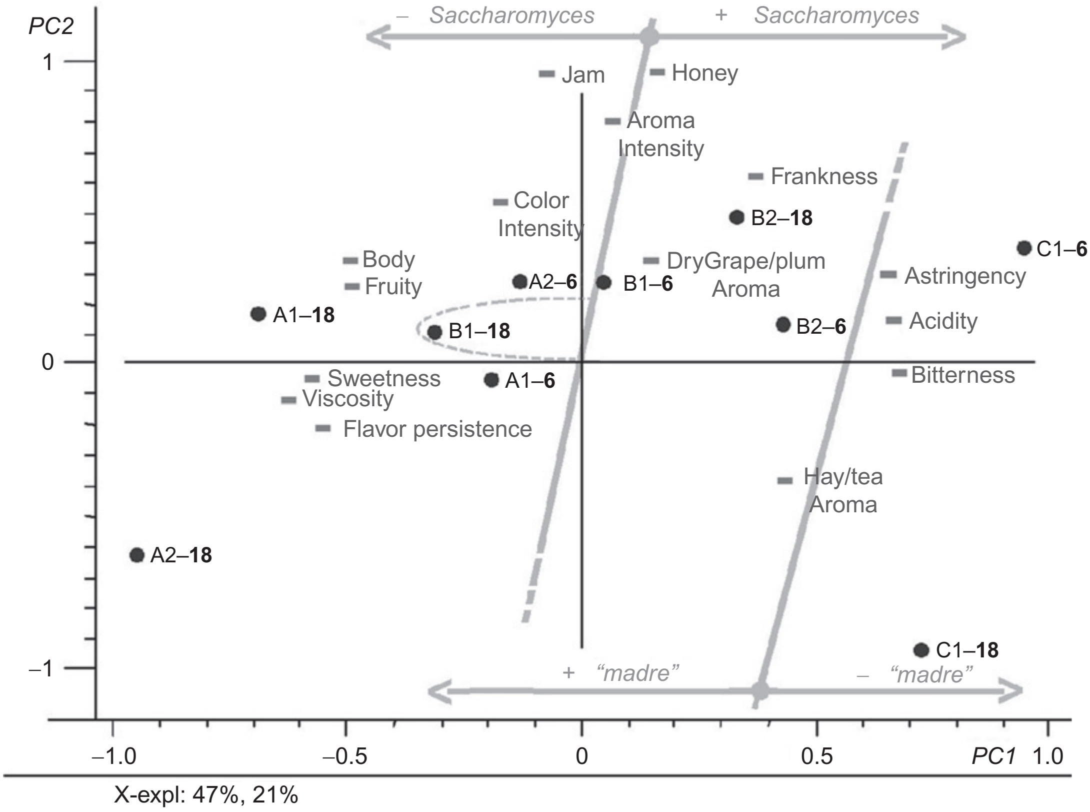

FIGURE 3.9 Principal component analysis projection of the sensory attributes of the Vin Santo obtained after 6 and 18 months of aging. Gray lines indicate the separation of the trials in relation to the use/nonuse of Vin Santo *madre* and of the commercial *Saccharomyces* strain, in their respective fermentations. (Legend: A1, fermentation with *madre* addition and no yeast strain inoculation, under vinsantaia conditions; A2, as A1, but under cellar conditions; B1, fermentation with *madre* addition and yeast strain inoculation, under *vinsantaia* conditions; B2, as B1, but under cellar conditions; C1, fermentation with yeast strain inoculation but without *madre* addition, under *vinsantaia* conditions). (from Domizio *et al.*, 2007)

of Sherry wines, was the only *Saccharomyces* strain that could dominate the wild microflora during the fermentation trials for Vin Santo production (Domizio *et al.*, 2008).

Most of the studies regarding the selection of a fermentation starter are mainly related to the production of other *passito* wines, rather than Vin Santo, with similar characteristics and therefore useful for their possible applications in Vin Santo production.

Saccharomyces species other than *S. cerevisiae* have often been found during spontaneous fermentation of sweet wines, such as *S. bayanus* and *S. paradoxus* during the natural fermentation of Tokaj wine (Naumov *et al.*, 2000, 2002; Sipiczki *et al.*, 2001) and *S. uvarum* in the natural fermentation for the production of Recioto and Amarone wines (Dellaglio *et al.*, 2003; Torriani *et al.*, 1999; Tosi *et al.*, 2009; Zapparoli *et al.*, 2003).

Beyond their ecological significance, most of these studies have been inspired by selection programs for typical strains for the production of these particular kinds of wines. For this purpose, most studies carried out have considered the use of cryotolerant strains of *Saccharomyces*, belonging to the physiological races of *uvarum* and *bayanus*, as these have been characterized for their ability to carry out alcoholic fermentation at low temperatures with low production of acetic acid, and high levels of glycerol and succinic acid, when compared with non-cryotolerant *Saccharomyces* (Castellari *et al*., 1992; Dellaglio *et al*., 2003; Giudici *et al*., 1995; Naumov *et al*., 2000). Indeed, evidence has shown a high production of acetic acid when *S. cerevisiae* ferments musts with a high sugar concentration, a stress factor that promoted up-regulation of structural genes involved in the formation of acetic acid from acetaldeyde (Caridi *et al*., 1999; Erasmus *et al*., 2003).

Accordingly, Muratore *et al.* (2007) used a *S. uvarum* strain for the fermentation of Malvasia delle Lipari, a grape variety that is also used for the production of sweet wine, and they investigated further the chemical and sensory properties of the relevant wines, comparing the results with those obtained with a commercial strain of *S. cerevisiae.* Lower volatile acidity, lower alcohol content, and higher total acidity were reported for the wine produced by *S. uvarum*, with higher scores for positive attributes assigned by a panel for the wine fermented with *S. uvarum*.

A *S. uvarum* strain that was isolated during fermentation for the production of Amarone was also used by Tosi *et al.* (2009). The technological and qualitative capabilities of this *S. uvarum* were evaluated and compared with those of a *S. cerevisiae* strain. Although *S. uvarum* did not complete the sugar fermentation, it showed a good fermentation rate, reaching 17.5% of ethanol 18.77% for the *S. cerevisiae* strain. The strain of *S. uvarum* was also characterized for its lower production of acetic acid and higher production of glycerol and higher alcohols, especially 2-phenyl ethanol, which is responsible for the notes of ''rose.'' Moreover, sensory evaluation of the wine fermented by *S. uvarum* permitted fruity and floral characters to be distinguished, thus with the obtaining of a similar bouquet to wines that are naturally fermented.

Malacrinò *et al.* (2005) also tested the fermentation ability of a commercial yeast that was a natural hybrid between *S. cerevisiae* and *S. bayanus*, which is appreciated for its vigorous fermentation at low temperatures in the production of Amarone wine. Despite the high sugar concentration of the must (35.4%), this yeast easily overcame the osmotic stress and showed a rapid start of the fermentation. However, stuck fermentation was observed with only 80% of the sugar consumed. The dilution of the must (sugar concentration of 32%) enabled this yeast to consume a higher percentage (98%) of the sugar.

Although inoculums of *Saccharomyces* strains can help to standardize these processes, in the case of Vin Santo, the wine could also be poorer if it is compared with those obtained with spontaneous fermentation (Domizio *et al*., 2007; Romani *et al*., 2011). In this last, the presence of a higher percentage of non-*Saccharomyces* yeasts appears to be one of the reasons for the higher complexity found in the relevant wine.

Indeed, the contributions of non-*Saccharomyces* wine yeasts to the analytical composition and the sensorial characteristics of wine are well documented (Egli *et al*., 1998; Lema *et al*., 1996; Moreira *et al*., 2005; Romano *et al*., 1992; Schütz and Gafner, 1993), and they show that non-*Saccharomyces* yeasts can lead to more complex aromas and improved wine quality (Ciani and Maccarelli, 1998; Ciani *et al*., 2010; Egli *et al*., 1998; Henick-Kling *et al*., 1998; Romano *et al*., 1997). This is due to the production of enzymes (e.g., esterases, β-glucosidase, proteases) involved in the release of aromatic compounds, which can therefore enhance a wine aroma (Fernández-González *et al*., 2003; Ferreira *et al*., 2002; Rojas *et al*., 2003; Rosi *et al*., 1994; Strauss *et al*., 2001). Moreover, non-*Saccharomyces* yeasts can promote a high production of glycerol (Ciani and Ferraro, 1996; Romano *et al*., 1997) and polysaccharides (Domizio *et al*., 2010; Romani *et al*., 2011), and thus they can increase the body of a wine. Besides, different non-*Saccharomyces* yeast, such as *C. zemplinina*, *C. stellata*, *T. delbrueckii*, *Z. bailii*, and *Z. rouxii*, can ferment substrates with high sugar concentrations (Benda, 1982; Lafon-Lafourcade, 1983; Martorell *et al*., 2007; Sipiczki, 2003), making the must more suitable for the subsequent fermentation by *Saccharomyces*.

On this basis, Cavagna *et al*. (2008) inoculated a must for the production of Vin Santo Trentino with two strains of non-*Saccharomyces* yeast: *C. zemplinina* and *Z. rouxii.* Due to their osmophile characters, both of these showed a good performance at the initial stages of the fermentation, and therefore, the Authors considered that these two strains are suitable for the initial stages of fermentation, to lower the sugar concentration of the must.

Over the past few years, with the aim to increase wine aroma and complexity, and at the same time to maintain control of the fermentative process to ensure the production of wines with repeatable characteristics, different studies have suggested the use non-*Saccharomyces* yeast as starters, in mixed culture with *S. cerevisiae* (Ciani *et al*., 2010). To date, however, few studies have considered the possibility of using mixed cultures also in Vin Santo production. On the other hand, Domizio *et al*. (2007) reported better sensorial ratings for texture, taste, and fruitiness, and thus for the overall good sensory quality in this Vin Santo, where together with the addition of the *madre*, the non-*Saccharomyces* yeasts persisted for a longer time along the alcoholic fermentation, with respect to those wines where *Saccharomyces* dominated and replaced the non-*Saccharomyces* yeasts from the early phases of alcoholic fermentation.

Accordingly, Ganucci *et al.* (2009) evaluated at laboratory scale the fermentative behavior of a *Z. rouxii* strain in the fermentation of must (44% sugar) obtained from dried Malvasia and Trebbiano grapes, used for Vin Santo production. This strain was able to dominate the indigenous population of *S. cerevisiae*, allowing to reach in the relevant wine the same ethanol concentration obtained in control trials inoculated with a *S. cerevisiae* strain. Moreover, lower levels of acetic acid and ethyl acetate were produced in the fermentations carried out by *Z. rouxii.*

Romani *et al*. (2011) also evaluated the yeast population dynamics and fermentation kinetics, and their influences on the analytical profiles of Vin Santo obtained at industrial scale utilizing in separate trials two non-*Saccharomyces* yeasts, *T. delbrueckii* and *Z. bailii*. These results were compared with those obtained both with spontaneous fermentation and with an inoculum of a *S. cerevisiae* yeast strain. The standard kinetics of fermentations were observed in all of the trials, also if a higher fermentation rate was observed in the trials inoculated with *S. cerevisiae* compared to those inoculated with the two non-*Saccharomyces* yeasts, and in the spontaneous one. A rapid decrease in non-*Saccharomyces* yeast was observed in the trials inoculated with *S. cerevisiae*. In these last ones, after 6 months, 18.4% ethanol was reached versus 16% of the trials inoculated with the non-*Saccharomyces* strains. No substantial differences were seen for the higher alcohols or other byproducts assayed.

Thus, the few results obtained so far using mixed starter cultures in Vin Santo production have been promising for the enhancement of the wine complexity, and to facilitate their commercial standardization, even if further investigations need to be carried out.

c. Fermentation process parameters and their influence on yeast dynamics and on the analytical and organoleptic profiles of Vin Santo Although the investigations mentioned so far have allowed a better understanding of the principal kinds of microorganisms involved in the process of making Vin Santo, little information has been given regarding the influence of the technological process parameters on the microbial dynamics and their consequent influence on the analytical and organoleptic profiles of the relevant wine.

With the aim to investigate yeast population dynamics during the production of Vin Santo under different fermentation conditions and to evaluate their impact on wine sensorial characteristics, Domizio *et al.* (2007) tested different fermentation conditions, such as yeast inoculum, *madre* addition, and temperature. The results indicate that the low temperatures that occurred during the initial stages of fermentation have different effects on the wine yeasts (Fig. 3.10). On the one hand,

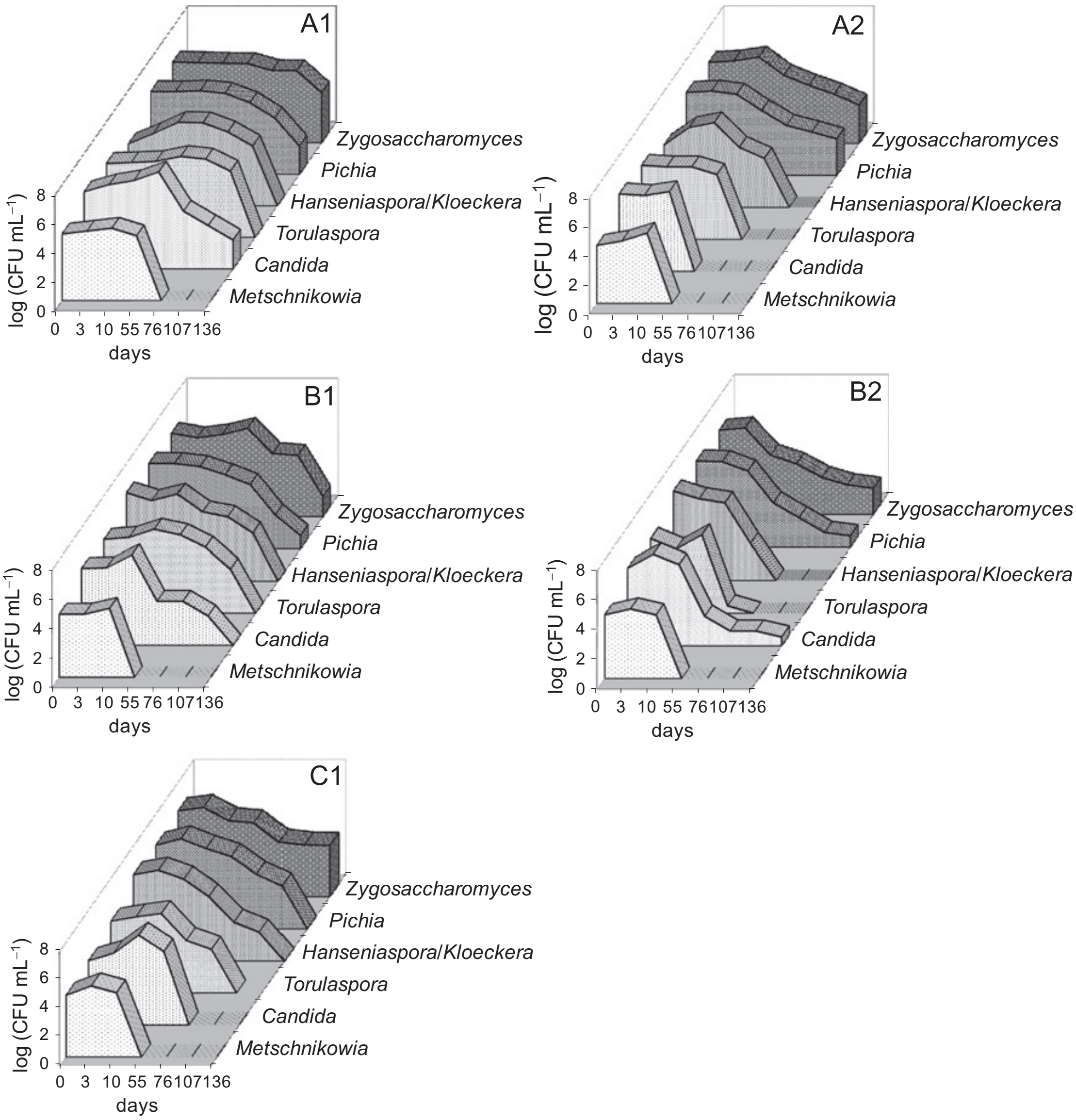

FIGURE 3.10 Yeast growth kinetics of the different genera of non-*Saccharomyces* yeasts during the fermentation trials for Vin Santo production; see Fig. 3.9 legend (elaborated from Domizio *et al.*, 2007)

the low temperatures had a negative influence on the growth of spontaneous or inoculated *S. cerevisiae* strains, which reached a peak in cell concentration only when the temperature started to get warmer. On the other hand, they probably decreased the ethanol sensitivity of the yeasts (Chaney *et al.*, 2006; Fleet, 2003; Gao and Fleet, 1988; Heard and Fleet, 1988), thus allowing the non-*Saccharomyces* yeasts to prolong their survival during fermentation. In fact the non-*Saccharomyces* strains present in the barrels under *vinsantaia* conditions, where they have a temperature constantly under 10 °C during the first 2 months, remained at elevated concentrations during this period, both without and with the commercial yeast starter inoculum. In contrast, they decreased rapidly even after 10 days when the fermentation was carried out in the cellar, at a constant temperature of 16–18 °C. The non-*Saccharomyces* population was mainly represented by yeasts of the genera *Candida*, *Hanseniaspora/Kloeckera*, *Pichia* and, especially, *Zygosaccharomyces*. This last yeast, moreover, was present in the must at the beginning of fermentation at higher concentrations, and under all conditions it was generally the only yeast present also after 5 months of fermentation.

The content inside the *madre* of lees, macromolecules such as mannan and gums and other chemical substances (Tachis, 2003) probably influence the sensory attributes of the wine. Indeed, Domizio *et al*., (2007) observed that following *madre* addition, the wines showed a general evolution toward a greater structure complexity, with higher scores for sweetness, viscosity, body, and flavor persistency. This trend also characterized the wine obtained with both *madre* addition and inoculum of the commercial *Saccharomyces* under the *vinsantaia* aging, although not under cellar aging, at constant temperature. Under this latter condition, the wine showed instead a tendency toward a greater intensity and frankness of the aroma, and to jam, honey, and dry fruit aroma; it also maintained a close relationship to the taste attributes of acidity, astringency, and bitterness and, on the contrary, a poor correlation with sweetness, fruitiness, viscosity, body, and flavor persistency. These results are also probably related to the behavior of the commercial *S. cerevisiae* strain that promoted (especially under the cellar conditions) the faster reaching of higher levels of ethanol, and consequently dominated the whole fermentation process, thus not allowing the non-*Saccharomyces* strains to have their full potential roles in the fermentation process. This hypothesis was also supported by the results of wines aged in the *vinsantaia*, in which a large inoculum of *Saccharomyces* resulted in a poorer product.

In the fermentations under the cellar conditions, higher ethanol concentrations were reached compared with those under the *vinsantaia* temperature conditions. This could be due to the combined stress effects on the yeasts of alcohol and high temperatures during the summer period in the *vinsantaia* aging. In the Vin Santo obtained without inoculation with the commercial starter, satisfactory ethanol levels were however reached (13.7–15.3%, v/v).

In a more recent study, Lencioni *et al*. (2009) reported the chemical composition and perceivable characteristics of wine obtained under ambient conditions (*vinsantaia*) with and without addition of *madre* and using different strains of *S. cerevisiae*. It was found that the different *S. cerevisiae* strains showed different fermentation behaviors and produced wines with different compositional and organoleptic characteristics. In particular, by the fermentations conducted with *madre* addition it was reached higher alcohol content and a greater structural complexity and flavor persistency, while the wines obtained with the yeast inoculum and without the *madre* addition generally showed lower contents of acetaldehyde and higher of alcohols.

E. Maturation in barrels

In normal wine making, the maturation period represents the phase of aging between alcoholic fermentation and bottling, during which a range of physical, chemical, and biological changes can occur (Jackson, 2008). Many studies have been carried out to determine any correlations among these changes and the main wine-making parameters, such as oxygen, cellar temperature and humidity, and container material (Boulton *et al.*, 1998). When maturation occurs in wooden barrels, the effects such as the extraction of wood compounds and wine evaporation through the wood have been studied in depth for red and white wine making, as well as for the interactions with the yeast lees (Escot *et al.*, 2001; Fornairon-Bonnefond and Salmon, 2003; Salmon *et al.*, 2000; Singleton, 1974).

In Vin Santo, due to the slow sugar metabolism, maturation already starts when the alcoholic fermentation has still not reached completion. Furthermore, depending on the initial sugar content and on the other process parameters, maturation of Vin Santo can generally last 2–4 years, and in some case more (Tachis, 2003).

Even if some producers might now use different rooms for Vin Santo aging, traditionally the barrels filled with must from dried grapes are stored in the *vinsantaia*, which is the attic in the local wineries, with the ventilation managed by opening the windows. The wines are left to mature fully in their barrels, and then once they had reached the required quality, they are ranked and blended to form the vintage to be bottled.

When most of the sugars are fermented, and according to the different traditional regional processes, the wine can be racked several times, to remove the gross lees. These gross lees can sometimes be the origin of unpleasant aromas when they remain in contact with the wine for any length of time (Rankine 1963; Tachis, 2003). However, while racking is normally done at least twice a year, as for both Vin Santo of Vigoleno (Barbieri 2003) and Vino Santo Trentino (Scienza, 2006), for Tuscany Vin Santo this is rarely done (Tachis, 2003), and will anyway depend on the decision of the individual winemaker.

According to traditional process, during maturation, the wines are subjected to fluctuating seasonal temperature extremes that, in relation to the length of the aging period, can lead to significant losses due to evaporation. These extremes of temperature also strongly influence the chemical and physical transformations in the wine, with important consequences for their perceived characteristics. Moreover, due to the partial filling of barrels (generally 80–90% of their volume), a relatively large wine–air interfaces is provided, resulting in oxidative conditions during the aging period (Tachis, 2003). Therefore, temperature and oxygen, which deeply influence wine fermentation and aging (Boulton *et al.*, 1998), are poorly controlled during the traditional Vin Santo maturation. Indeed, according to traditional practices, it is rare for any other rational actions to be applied, such as the complete filling of barrels or similar, which might be aimed at better management of these parameters, so making the success of the product left to chance. This accounts for the considerable variability in the quality of different vintages.

For the influence of these above-mentioned parameters on long-term Vin Santo aging, so far there have been few scientific studies that have focused on this kind of wine. Therefore, objectively, to date it is difficult for the industry to gain knowledge that will help to better manage the organoleptic characteristics of this type of wine.

As a consequence of both the several rackings and the partial barrel filling, Vin Santo undergoes more or less strong oxidative conditions during the maturation period. On the other hand, as well as an acceptable level of oxidation depending on the type of wine, it is also generally considered that oxidation is favorable for the correct development of the aroma of wine such as Vin Santo.

As is known, during the maturation period, oxygen promote deep changes also in the phenolic compounds. In particular, polyphenol oxidation determines the production of brown compounds, and as aging proceeds, a darkening of the color of the wine can be seen (Singleton, 1987, 1995). As a consequence, Vin Santo is sometimes characterized by a natural color that ranges from golden straw to intense amber.

Oxygen is also responsible for chemical reactions involved in the production of compounds determining for the typical aromatic complexity of Vin Santo. In particular, there are those reactions coupled to autooxidation of certain phenolic compounds (Wildenradt and Singleton, 1974), which can lead to the oxidation of ethanol to acetaldehyde. This acetaldehyde, the flavor threshold of which in wine is normally 100–125 mg L^{-1} (Zoecklein *et al.*, 1995) provides at low concentrations a pleasant fruity aroma, although this is perceived as a pungent irritating odor at high concentrations (Miyake and Shibamoto, 1993). On the other hand, according to Tachis (1988), acetaldehyde has a little influence on the organoleptic perception of the Vin Santo, where normally it is present in the concentration ranging from 40 to 180 mg L^{-1}. Instead, in other wines maturated under oxidative conditions, such as the Sherry wines, due also to the actions of the flor yeasts, the acetaldehyde can reach level higher than 500 mg L^{-1} (Liu and Pilone, 2000).

To date, there have been a few fragmented studies that have correlated the complex phenomena during maturation with the organoleptic characteristics of this kind of wine. As mentioned above, during normal maturation in wooden barrels, water and ethanol evaporation is observed, and as a consequence, an increase of low-volatility compounds and non-volatile compounds might be expected. These effects are variable, depending also on the shape and size of the container, as well as on the environmental conditions, such as temperature and room humidity (Boulton *et al.*, 1998). Indeed, when the relative humidity is low, the water evaporates more rapidly than the ethanol, increasing the ethanol concentration. In contrast, with high relative humidity, water evaporation is suppressed, but not that of alcohol, with a consequent light decrease in the alcoholic strength. Accordingly, as the relative humidity in *vinsantaia* is season dependent, fluctuating concentrations of some different wine compounds are observed.

The evolution of the chemical and sensorial characteristics of Vin Santo made under different experimental conditions has been reported by Domizio *et al*. (2007). Although the data are referred to an aging period of 18 months, from the treatments tested, the study provided evidence that for the evolution of the sensorial characteristics of the wine obtained, the addition to must of *madre* and inoculum of starter strains had a stronger influence than the environmental temperature of aging had. The overall results obtained indicated also that the small differences seen among all of the organoleptic attributes were already perceived in 6-month-aged wines and became more amplified in the 18-month-aged wines (Figs. 3.9 and 3.11).

Indeed, after a maturation period of 18 months, no significant differences were seen between the wines obtained without the yeast inoculums, either if they were aged in *vinsantaia* or at a constant temperature of 18 °C, except for the honey character and the color intensity. Similarly, also inside the cluster of wines obtained with both the yeast inoculum and the addition of *madre* there were no differences found in the perception of individual sensory attributes. However, the wines from the yeast-inoculated fermentation with the addition of *madre* were perceived to be more acidic, astringent, bitter, and viscous than the non-inoculated wines when they were aged in the cellar at constant temperature (18 °C). In contrast, there were no significant differences among the wines aged under the traditional conditions (*vinsantaia*).

The wine made with the commercial yeast strain but without the addition of *madre* was perceived to show less color intensity, fruitiness, sweetness, body, and viscosity, as compared to all of the other wines. This wine was perceived instead to be more acidic in comparison to the other wines.

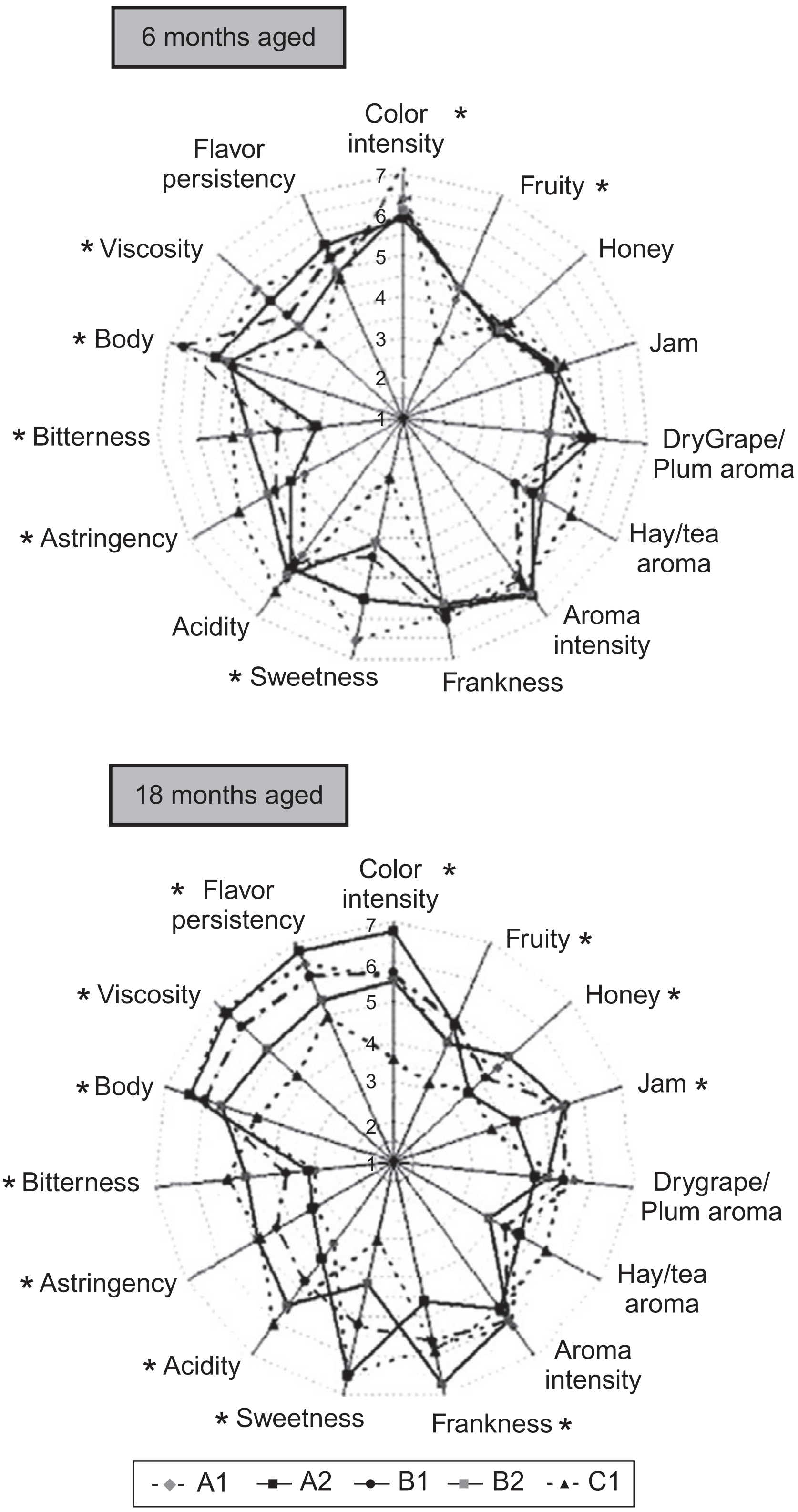

FIGURE 3.11 Differences in the sensorial characteristics of the Vin Santo obtained after 6 and 18 months of aging. The values (conditions as indicated) represent the means of two complete replicates, based on nine point scales (*indicates a sensory attribute with at least one of the population means significantly different at the 0.1 α level with respect to the others, on the basis of ANOVA; see Fig. 3.9 legend. (from Domizio *et al*., 2007)

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