PREPARATION AND EVALUATION OF STRAWBERRY WINE

THESIS

by

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Dedicated

to

Dadi ji

and reverend

Ammi ji & Papa ji

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CERTIFICATE-I

This is to certify that the thesis entitled **"Preparation and Evaluation of Strawberry Wine"**, submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (POSTHARVEST TECHNOLOGY)** to Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Somesh Sharma (H-98-36-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated : 24July, 2000

(V.K.JOSHI)

CERTIFICATE-II

This is to certify that the thesis entitled **"Preparation and Evaluation of Strawberry Wine"**, submitted by **Mr. Somesh Sharma (H-98-36-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P), in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (POSTHARVEST TECHNOLOGY)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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(Somesh Sharma)

CONTENTS

LIST OF ABBREVIATIONS

TCU	Tintometer colour units
SO_2	Sulphur dioxide
AA	Acetic acid
KMS	Potassium metabisulphite
%	Per cent
°B	Degree brix
TSS	Total soluble solids
cm	Centimeter
Hrs	Hours
Min	Minute
CO_2	Carbon dioxide
DAHP	Diammonium hydrogen phsophate
PCA	Principal Component Analysis
PC	Principal Component
RF	Rate of fermentation

Chapter 1

INTRODUCTION

Strawberry (*Fragaria ananassa* Duchesne) is one of the important temperate fruits grown throughout the world. The world production of strawberry was 2687 thousand metric tonnes during 1998, which increased to about 2784 thousand metric tonnes in the year 1999 (Anon. 1999). In India, the cultivation of strawberry is undertaken in various parts of Maharashtra, hills of Uttar Pradesh and Himachal Pradesh. In recent years, the commercial cultivation of strawberry has increased considerably in Himachal Pradesh mainly in Sirmour, Solan, Una, Kangra and Kullu districts but the exact area and production is not yet documented.

The fruit of strawberry is bestowed with an attractive colour, flavour and taste which is difficult to put into words and is rated high on the list of preferred fruits. But strawberry fruits are highly perishable in nature, characterised by a limited postharvest shelf-life. Due to this, a lot of produce, mainly undersized and deformed fruits, goes waste. Furthermore, even the best graded quality fruits, if not marketed well in time, also reduce their value. These fruits can be utilized for preparation of various products such as jams, juices, jellies, ice cream etc. (Spayd and Morris, 1981). The fruit has a potential for conversion into alcoholic beverages like wine. It will not only save the precious resources from wastage but would also increase economic returns to the strawberry growers.

Wine is perhaps the oldest known alcoholic beverage, which traces its antiquity to atleast 5000 BC. Wine has long association with human, artistic, cultural and religious activities. The old testament refers to the wine and sanctifies its use in mass baptism and other formal ceremonies. Wines have always been considered as safe and healthy drinks, besides an important adjunct to the diet. In wines, ethanol is a macro-nutrient energy source, capable of providing calories for all essential biological activities of the human being; cells, energy for physical work and thermogenesis (Bisson, 1995). Recent findings have also indicated that consumption of red wine is perhaps the miracle savior since phenolic compounds in the wine help to combat heart diseases and other ailments (Muller, 1995). Michael *et al.* (1993) and Meshiang *et al.* (1997) found that phytoalexins found in grapes had cancer chemopreventive activity. A review of recent studies have also shown the beneficial effects of wine consumption due to phenolics and alcohol in wine, which protect human body from free radical attack and increases HDL level in the body (Joshi, 1997). Sonia *et al.* (1992) reported that 8-18% of ethanol (% v/v) can inhibit bacteria, yeast and mould growth but effectiveness depends upon different physical and environmental factors.

Large quantity of wines are produced all over the world. The estimated world production of wine during 1999 was 25832 thousand metric tonnes. Italy and France are the leading wine producing countries and India stands nowhere on the wine producing map (Anon. 1998). India is the second largest fruit producer and producing around 9 per cent of the total world fruit production (Sarin, 1999). There are numerous reports available on wine preparation from fruits such as plum (Vyas and Joshi, 1982; Joshi *et al.*, 1991), apple (Joshi and Bhutani, 1991; Sandhu and Joshi, 1995), apricot (Joshi and Sharma, 1994), pomegranate (Adsule and Kadam, 1995) etc. Inspite of large scale production of fruits every year and availability of technology, fruit wine production is negligible in India compared to the production of huge quantity of molasses based 'hard liquor' (Rao, 1989; Joshi, 1997; Sandhu and Joshi, 1995).

The quality of grape wine is known to depend upon number of factors like cultivars and their characteristics like adequate sugar level, acid content, colour and aroma (Ethiraj and Suresh, 1993). The method of wine production also affects the quality of wine (Timberlake and Bridle, 1976). Evaluation of proper cultivar and the method of preparation for the production of quality strawberry wine is essential. However, no such information is available for strawberry wine.

Being perishable in nature, the fruit has to be disposed-off, but poor utilization of the culled and undersized fruits by the processing industries lead to considerable postharvest losses (30-40%) which can be compensated by the production of strawberry wine. Considering the postharvest technology and infrastructure available coupled with the scope of strawberry wine, the studies on the evaluation of strawberry cultivar, suitable for wine production were planned. The studies were conducted with the following objectives:

i) To standardize the technique for wine preparation and evaluation for various physico-chemical and sensory characteristics

ii) To screen different cultivars for suitability of wine production

iii) To determine changes occurring in wine during maturation

iv) To work out the economics of the product

Chapter 2

REVIEW OF LITERATURE

Strawberry (*Fragaria ananassa* Duchesne), an important fruit of family Rosaceae, occupies an important place among the small fruit plants. It is a delicious but highly perishable fruit needing immediate utilization as dessert fruit or processed product. Preparation of alcoholic beverages including strawberry wine is another outlet for its economic utilization but scanty published information on the method and the cultivars suitable for wine preparation is available. A brief review of the relevant literature on the preparation and evaluation of strawberry wines or related fruit wines has been made and discussed hereunder:

2.1 STRAWBERRY PRODUCTION, COMPOSITION AND UTILIZATION

2.2 WINE PRODUCTION TECHNOLOGY

2.3 COMPOSITION OF WINE

2.4 BIOCHEMICAL CHANGES DURING MATURATION

2.5 MICROBIOLOGICAL QUALITIES

2.6 SENSORY QUALITIES

2.1 STRAWBERRY PRODUCTION, COMPOSITION AND UTILIZATION

2.1.1 Production

The strawberry is grown throughout the world. The major strawberry producing countries of the world are USA, Spain, Japan, Poland, Korea and Russian Federation (Anon. 1999). Strawberry production of some of the countries is shown in Fig. 2.1.1. The estimated production of strawberries in the world during 1999 was 2784 thousand metric tonnes (Anon. 1999). But there is no data available regarding

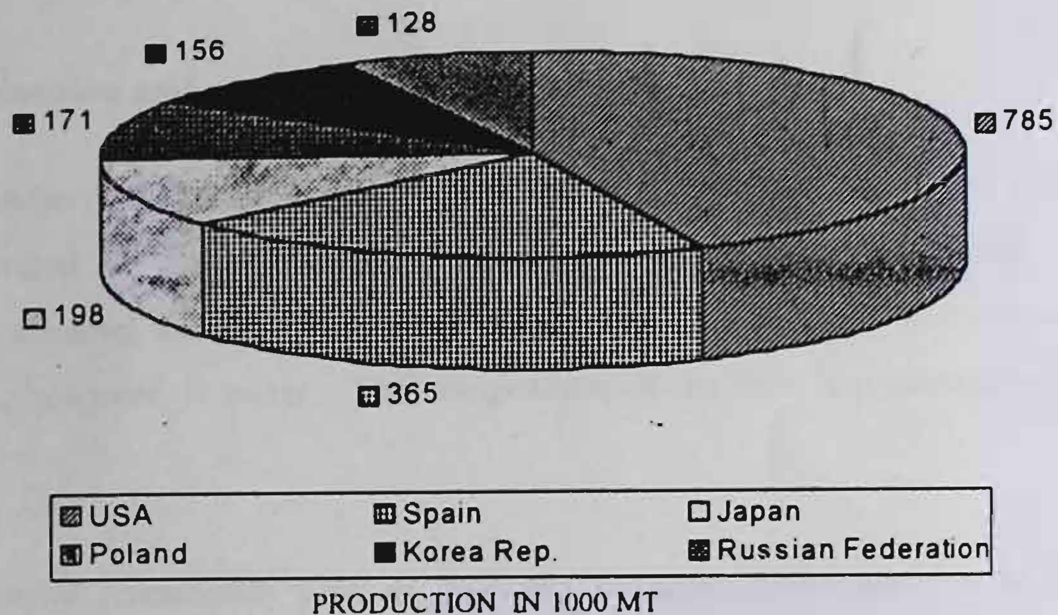


Fig. 2.1.1. Major strawberry producing countries of the world and their production during 1999 (FAO, 1999)

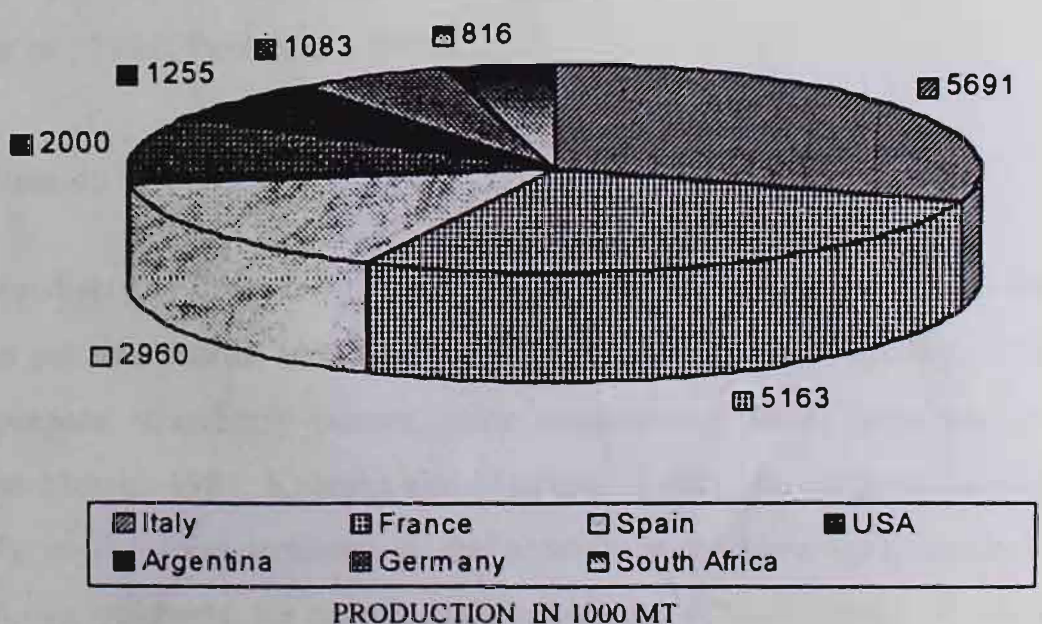


Fig. 2.2.1. Major wine producing countries of the world and their production during 1998 (FAO, 1998)

the production in India, where it is cultivated near the vicinity of metropolitan cities, some areas of Himachal Pradesh, Haryana, Jammu and Kashmir, Uttar Pradesh (Dehradun), Maharashtra (Mahabaleshwar).

2.1.2 Composition and nutritive value

Strawberry is rich in vitamin C, iron and other minerals. Strawberry flavour is characterised as fruity, sweet and tart The aroma notes are floral, green strawberry, caramel and fruity in nature (Nagy, 1993). The major constituent like other fruits. however, is water. The composition of the fruit is presented in Table 2.1.1.

Phenolic compounds such as quercitin, catechin, chlorogenic acid, ferulic acid, ellagic acid are present in the strawberry fruits (Kader and Barret, 1996). Strawberry aroma is mainly determined by a complex mixture of esters, aldehydes, alcohols and sulfur compounds which have been extensively studied (McFadden *et al.*, 1965; Dirinck *et al.*, 1981). Esters are responsible for imparting the fruity and floral notes to the fruit. Ethyl and methyl esters are qualitatively and quantitatively, the most important class of volatile compounds in strawberry flavour and aroma (Dirinck *et al.*, 1981; Perz *et al.*, 1992).

2.1.3 Utilization

Strawberry is deep red in colour, with a unique shape and a flavour that is difficult to put into words, is utilized or relished for its dessert quality. The fruit is used to prepare strawberry purees, juice concentrate, juice, jams and preserves (Spayd and Morris, 1981; Kotecha and Madhavi, 1995). Strawberry flavour is used extensively in the food industry in the production of beverages, confectioneries, bakery fillings, yoghurts, ice creams, cake mixes etc. (Deuel, 1996). Even then, due to highly perishable nature of the fruit, a substantial part of the produce is wasted.

Table 2.1.1 Composition of strawberry fruit

Constituents	Average range
Edible portion (%)	97%
Water (%)	89 9-92 4
Total soluble solids (°B)	7-10 2
Total sugars (%)	3 3-9 1
Sucrose (%)	0 2-2 5
Fructose(%)	1 7-3 5
Glucose (%)	1 4-3 1
Titratable acidity (%)	0 52-2 26
Organic acids	
Citric (mg/100g)	420-1240
Malic (mg/100g)	90-680
Ascorbic (mg/100g)	26-120
Succinic (mg/100g)	100
Tartaric (mg/100g)	17
Pyruvic (mg/100g)	5
Shikimic (mg/100g)	Trace
Total phenols (mg/l)	58-210
Protein (%)	0 23
Total anthocyanin (mg/l)	55-145
Minerals	
Potassium (mg/100g)	130
Sodium (mg/100g)	6
Calcium (mg/100g)	13
Magnesium (mg/100g)	8
Iron (mg/100g)	0 6
Zinc (mg/100g)	0 2

Source : Green, 1971; Wills, 1987; Kader, 1991; Kim *et al* , 1993; Gorsel *et al* , 1992; Hulme, 1978

2.2 WINE PRODUCTION TECHNOLOGY

2.2.1 Wine production

The estimated world production of wine during 1998 was 25832 thousand metric tonnes out of which Italy alone produced 5691 metric tonnes (Anon. 1998). India stands nowhere on the wine production map of the world. The countrywise wine production of the world is presented in Fig. 2.2.1.

Theoretically, wine can be prepared from any fruit having fermentable sugars and nutrients required for fermentation (Amerine *et al.*, 1980). Grape has been a fruit of choice for the preparation of wine. There are 20 different species of grape vine but only one viz. Vitis vinifera, seems to be good for wine making. Within one species there are over 5000 cultivars and though scientists have isolated thousands of flavour traces, only 50 to 60 grape cultivars add a recognizable flavour to the stuff in the glass. However, studies on production of wine from different fruits have been reported in the literature such as apple (Rana *et al.*, 1986; Joshi and Bhutani, 1991, Joshi, 1997), plum (Vyas and Joshi, 1982; Joshi *et al.*, 1991), pomegranate (Adsule and Kadam, 1995), red raspberry (Rommel *et al.*, 1990). There is no published information on preparation of wine from strawberry except for a scattered report (Pilando *et al.*, 1985).

2.2.2 Methodology

Basically, the preparation of wine from other fruits is similar to grape. Wine making from fruits like plum, banana, mango, pomegranate, peach, apricot has been reported (Kundu *et al.*, 1976; Vyas and Joshi, 1982; Onkarayya, 1986, Adsule and Kadam, 1995; Joshi, 1997). Unlike the grapes, the fruits of strawberry are highly acidic in nature like plum or apricot. But they possess colour to make wine of appealing colour. Besides, the fruit is pulpy and thus, its fermentation is carried out to make wine. Not only this, the fruits have lower sugar content than the grapes thus, ameliorating the pulp to the desired level is essential.

From methodology point of view, strawberry wine resemble with stone fruits. In preparation of plum wines, fully ripe fruits are used. These are diluted with water in 1:1 ratio, added with 0.3% pectinol, 150 ppm SO_2 and enough sugar to raise TSS of the must to 24°B. The pulp is fermented to produce wine (Vyas and Joshi, 1982). Fermentation of plum must with or without skin affects the physico-chemical characteristics of the wine. Like plum, strawberry fruits are highly acidic in nature and to make a palatable wine, dilution of pulp with water is the alternative available. The use of an yeast *Schizosaccharomyces pombe* as a deacidifying agent in plum must besides *Saccharomyces cerevisiae* var. *ellipsoideus* used for alcohol production has been made (Azad *et al.*, 1987).

A method for preparation of peach wine has also been described (Joshi *et al.*, 1999). For peach wine, dilution of pulp in ratio of 1:1 raising initial TSS to 24°B and 100 ppm SO_2 produced wines with acceptable sensory quality. Since strawberry fruit has acidity similar to the peach fruit, a similar dilution seems to be appropriate.

Pasteurized and depectinized red raspberry wine by addition of 100 ppm of liquid pectic enzyme was the most acceptable from sensory and colour stability point of view (Rommel *et al.*, 1990). Use of 50 to 100 ppm SO_2, 2 to 5% yeast inoculum, 3.5 to 4.0 pH for preparation of good quality wine is recommended (Salunkhe and Kadam, 1995). Whereas, Adsule and Kadam (1995) reported that 100 ppm SO_2, 10 per cent inoculum, 4.0 pH were the optimum conditions for preparation of good quality pomegranate wine.

2.2.2.1 Pretreatments

In the grapes to prepare quality red wine, several processes like crushing, carbonic maceration, thermovinification and fermented on the skin are practised (Amerine *et al.*, 1980; Zoecklein *et al.*, 1995).

Crushing

Grapes are crushed and destemmed as soon as possible after harvest. Crushing releases the juice and activates enzymes liberated from damaged grape cells (Jackson, 1999).

Carbonic maceration

Carbonic maceration is very ancient but technically a simple process. For the last half a century, it has come under close scientific scrutiny in Southern France (Flanzy *et al.*, 1990). The most well known wine employing carbonic maceration is Beaujolais. Andre (1973) recommended heating the whole grapes to 35°C before carbonic maceration for a period of 10 days followed by crushing and cooling. Later on Beelman and Mcardle (1974) kept the whole grapes under CO_2 for 21 days, after removal from CO_2 de-stemmed and crushed, treated with 75 ppm SO_2 and pressed. The pressed juice was fermented. Lorincz *et al.* (1998) kept grapes under CO_2 pressure for 7-12 days at 30-32°C and later on free run juice was drawn-off, and then, grapes were crushed and destemmed. The juice was fermented subsequently. Vinification involving longer CO_2 maceration time proved suitable to prepare very mellow red wines. The longer carbonic maceration time (14-20 days) considerably increased the phenolic constituents of the wine (Lorincz *et al.*, 1998). Amerine and Ough (1972) reported that fermenting must under strongly reducing (low oxygen) conditions or in the pressure fermentations have slightly higher alcohol levels. Benard *et al.* (1971) found that holding whole grapes under CO_2 pressure slows down fermentation and consequently, helps in preventing an undue rise in temperature.

Thermovinification

It is uncommon that grape musts need colour adjustment before fermentation. Thermovinification is used to improve colour extraction from weakly coloured grape cultivars (Rapp *et al.*, 1992). In addition, thermovinification favours the wines which initially are deeper in colour than their traditionally fermented counterparts, although clarification may be slower because of increased phenolic extraction. Wrolstad *et al.* (1980) found that blanching improved the colour stability of strawberry juice. Joslyn and Goldstein (1964) observed that heating of berries at 74°C for period of only 1 min. was sufficient for colour extraction in carginane grapes.

Fermented on the skin

For production of red table wine, the crushed grapes should be fermented alongwith their skin for some time i.e. until reasonable amount of colour gets extracted to impart the wine dark red colour (Joshi, 1997). Sims and Bates (1994) reported that maximum colour and anthocyanin extraction occurred within four days of skin fermentation at optimum maturity of fruits but continued through 6 days with later maturity fruits. However, the wines had less muscadine aroma and were more astringent.

2.3 COMPOSITION OF WINE

A typical wine contains sugars, acids, ethyl alcohol, higher alcohols or fusel oils, tannins, aldehydes, esters, amino acids, minerals, vitamins, anthocyanin, fatty acids, minor constituents like methanol, a number of flavouring compounds etc. Physico-chemical characteristics of some of the wines are summarized in Table 2.3.1.

2.3.1 Titratabie acidity

Titratable acidity of any fruit wine is an important characteristic varying between 0.5 to 1.0 per cent in different fruit wines (Table 2.3.1). The acidity of fruit wine is dependent upon a number of factors like type of fruit, method of preparation and type of yeast used. Carbonic macerated wines havdless titratable acid, malate and tartarate concentration. (Amerine and Ough, 1968; Benard *et al.*, 1971; Beelman and Mcardle, 1974; Carroll, 1986; Ricardo-da-Silva *et al.*, 1993).

Table 2.3.1 Physico-chemical characteristics of different fruit wines

Characteristics	Range		
	Plum wine[a]	Peach wine[b]	Apple wine[c]
Total soluble solids (°B)	8.0-12.0	7.6-9.1	4.6-7.5
Titratable acidity(%)	0.62-0.68	0.61-0.80	0.37-0.41
Volatile acidity (% A.A)	0.028-0.040	0.020-0.029	0.021-0.105
Ethanol (% v/v)	8.5-11.0	10.6-11.6	10.50-12.8
Total esters	104-109	90.9-101.5	76.80
Total phenols (mg/l)	-	206-278	124.50
Colour - Tintometer colour units (TCU)			
Red	6-10	5-7	-
Yellow	10	8-18	-

[a]Joshi *et al.*, 1990; Joshi and Bhutani, 1990; Vyas and Joshi (1982)

[b]Joshi *et al.* 1999

[c]Yang and Wiegand, 1949; Joshi, 1997

2.3.2 Ethanol

Ethanol is the component on which the type of wine can be characterized. Table wines usually contain 11 to 14 per cent alcohol but may have as low as 7 per cent (Joshi, 1997). The ethanol content in wine is influenced by method of wine preparation, type of yeast used, initial TSS etc (Joshi and Bhutani, 1990; Joshi and Sharma, 1994; Joshi, 1997). Alcohol was found slightly lower in wines produced by carbonic maceration (Beelman and Mcardle, 1974; Carroll, 1986). But lower alcohol content was surprising since it conflicted with the earlier report of higher alcohol yields found with this process (Amerine and Ough, 1968). The reason was traced to differences in natural yeast flora associated with fermentation of this treatment (Beelman and Mcardle, 1974). Further, longer period of carbonic maceration gave lower alcohol concentration than shorter period of carbonic maceration (Salinas *et al*., 1996). Not only this, red wines often have lower alcohol levels than white wines with the same initial sugar content (Zoecklein *et al.* 1995).

2.3.3 Higher alcohols

The formation of higher alcohols is the important criterion on which the acceptability of wine depends upon. The formation of these characteristics during fermentation is closely related with the type of yeast, cultivar of fruits and conditions during fermentation (Amerine *et al*., 1980; Houtman *et al*., 1980; Ciolfi *et al*., 1985). Lower content of higher alcohols in wines is desirable as they contribute to the flavour development (Gayon, 1978; Amerine *et al*., 1980; Fowles, 1989; Joshi, 1997). Higher alcohols in wines are formed due to amino acid biosynthesis from carbohydrates or directly from existing amino acids by deamination and decarboxylation (Amerine *et al*., 1980). Guymon *et al*. (1961) showed that oxidative conditions during fermentation favour production of more quantity of higher alcohols. The presence of pomace, as in red wine production aerates the wine, leading to formation of greater amount of higher alcohols. The higher alcohol amount in table wines varied from about 140 to 240 mg/l and in dessert wines from about 160 to 900 mg/l (Amerine *et al*., 1980). Fusel oil formation was the result of transamination of corresponding amino acid (Zoecklein *et al.* 1995). Rankie (1967) reported that grape cultivar and climatic variations influenced the fusel oil content irrespective of yeast strain, must pH and processing conditions.

2.3.4 Total phenolics

Amount of tannin in wine varied between 100 to 200 mg/l depending upon the type of wine, yeast fermentation conditions, containers and the maturation period (Amerine *et al*., 1980; Almela *et al*., 1991). Carbonic maceration of red grapes produced wines with lower phenols as compared with normally fermented juice

(Carroll, 1986). But earlier Timberlake and Bridle (1976) found that carbonic macerated wines contain more total phenolics than thermovinified wines and those fermented on the skin (Timberlake and Bridle, 1976). Longer carbonic maceration i.e. 14-20 days time made wines with higher total phenolics than those fermented on the skin. Wines prepared by cold carbonic maceration contained less phenolics than warm wines, respectively (Lorincz *et al.*, 1998). But earlier anaerobic treatment reduced the tannin extraction and wines of carbonic maceration were significantly poorer in tannins. It was found that total phenols level continued to increase through six days of skin fermentation, regardless of fruit maturity (Sims and Bates, 1994). Flavonoid bitterness in wines is primarily due to the Flavon-2-ols, (+) catechin, (-) epicatechin and their polymers (Arnold *et al.*, 1980). Thermal vinification might have an oxidizing effect or accelerated ageing effect on red wine resulting from condensation and precipitation of phenolic constituents (Zoecklein *et al.*, 1995).

2.3.5 Esters

The esters in wine are formed as a result of esterification of alcohols with the respective acids (Amerine *et al.*, 1980). The total esters of various wines reportedly vary between 200 to 400 mg/l as ethyl acetate (Amerine *et al.*, 1980 and Joshi, 1997). Esters in general, have fruity and floral impact characteristics that are important in sensory properties of wine (Zoecklein *et al.*, 1995). Gzochukwu *et al* (1994) found that aroma in palm wine appeared due to these different esters. Long period of carbonic maceration and then, ageing in new wood barrels, resulted in having higher ethylic esters (Salinas *et al.*, 1996). Esters present in wine include among many others, ethyl acetate which can be increased by fermentation or thermovinification, as the temperature of fermentation and fementable sugar levels affect the formation and concentrations of esters in wine (Zoecklein *et al.*, 1995).

2.3.6 Anthocyanin and colours

Numerous factors have been shown to influence the colour of red wines, but anthocyanin type, amount, content and cultivar maturity (Robinson *et al.*, 1966, Timberlake and Bridle, 1976; Flora, 1978) and skin contact dictate the red colour of the wine to a larger extent (Bates *et al.*, 1980; Scudamore-Smith *et al.*, 1990; Singleton and Trousdale, 1992). Thermovinified wines were found nearly twice as coloured as those fermented on the skin despite containing less anthocyanins and higher pH, which should have lessened the colour. Carbonic macerated wines are only one third as coloured as thermovinified wines (Timberlake and Bridle, 1976). Wines made from more mature fruits had greater colour intensity and higher levels of anthocyanins (Sims and Bates, 1994). Anthocyanin content in carbonic macerated free run wines showed higher value compared to those skin fermented or pressed wines. Further, the leucoanthocyanin content was found higher in carbonic macerated wines than skin fermented (Lorincz *et al.*, 1998). It was found that high extraction produced wine with more total pigments and phenols than low extraction time (Bakker *et al.*, 1998). In fact, skin contact has been shown to favour the release of aromatic compounds, which are localized mostly in the skin (Bayonove *et al.*, 1974 and Dubourdieu *et al.*, 1986). However, these compounds were more susceptible to browning, owing to larger extraction of phenolics from the grape solids (Ough, 1969; Ramey *et al.*, 1986; Cheynier *et al.*, 1989). Overripe fruits of Bentom and Totem cultivars of strawberry with higher anthocyanin and total phenolics gave wines with better colour than fully ripe fruit (Pilando *et al.*, 1985).

2.4 BIOCHEMICAL CHANGES DURING AGEING/MATURATION

Ageing is divided for convenience into minimally oxidative maturation (before bottling) and strictly reductive ageing (after bottling). Maturation involves several independent events that improve wine quality (Singleton, 1995).

2.4.1 Alcohol

Alcohols in wines react with organic acids like tartaric, malic, succinic and lactic acid to form esters which have been reported to increase with ageing of wines (Amerine *et al.*, 1980).

2.4.2 Volatile acidity

The concentration of total volatile compounds also increased during fermentation as well as in storage. During ageing, acetic acid (volatile acidity) can result from the coupled oxidation of wine phenolics to yield peroxide which in turn oxidizes ethanol to acetaldehyde and subsequently to acetic acid (Zoecklein et al. 1995).

2.4.3 High alcohols

Higher alcohols were formed throughout the fermentation and have been found to be closely related to aroma and taste of wine (Tzvetanov *et al.*, 1982 and Romano and Suzzi, 1993).

2.4.4 Colour changes

During maturation, decrease in tannins due to complexing of tannins with protein and polymerization takes place. Due to these changes, some of molecules become so massive that they precipitate, resulting in slow smoothening of the taste (Beridze, 1948; Ribereau-Gayon *et al.*, 1976 and Amerine *et al.*, 1980). The changes that occur during ageing, the most documented are those affecting colour. The polymerization of reactive phenolics and anthocyanin was found to be a major cause of colour deterioration in strawberry preserves (Abers and Wrolstad, 1979). During ageing of red wines, both coloured and non-coloured phenolics are reported to play important roles and durable quality is associated with high phenolic content (Haslam, 1989). These phenolic compounds undergo a number of transformations depending upon the temperature, sulfur dioxide concentration, degree of oxidation, time and the anthocyanate to tannin ratio (Zoecklein et al. 1995). Red wines lose their young purplish cast and initially become darker. As ageing continues, colour becomes less intense, starts to turn brickish and eventually becomes tawny (Jackson, 1999). So, in the red wines, colour changes largely reflect the polymerization and oxidation of anthocyanins and tannins (Dallas *et al.*, 1995). During storage in bottle, the content of the anthocyanins decreased and that of polymeric pigments increased in thermovinified, carbonic macerated and fermented on the skin wins.

Thermovinified and Carbonic macerated wines, however, increased in colour despite the anthocyanin losses (Timberlake and Bridle, 1976). Condensation reactions occur between anthocyanins and tannins which form anthocyanate complex, leading to intensification toward purple or tile red hues (Ribcreau-Gayon and Glories, 1986 and Recht, 1993). Pilando *et al.* (1985) reported that browning reaction was the sum of the oxidative browning reaction, Maillard browning and ascorbic acid browning.

Ascorbic acid has been found to accelerate destruction of anthocyanins pigments and contribute to browning (Poei-Langston and Wrolstad, 1981). Polyphenol oxidase (PPO) catalyzes browning reactions by acting on d-catechin present in strawberries (Wesche-Ebeling, 1980). Polymers were found as the major source of colour in partially aged strawberries wine and showed a tremendous decrease in anthocyanins after fermentation (Pilando *et al.*, 1985). Only 3 to 9 per *cent of anthocyanin contents, originally* present in the strawberry juice were recovered in strawberry wine. Maturation of grape wine increased the browning (Bakker, 1998). Wines made without SO_2 however, showed more browning than those with SO_2. The anthocyanins normally present in wines were rapidly lost to the trace levels after 24 months of maturation. Loss of anthocyanins and/or formation of brown compounds in strawberry and red raspberry products during storage have been attributed to many factors such as pH and acidity, phenolic compounds, sugars and sugar degradation products and oxygen (Markakis *et al.*, 1957; Wrolstad *et al.*, 1970; Rommel *et al.*, 1990; Withy *et al.*, 1993).

2.5 MICROBIOLOGICAL QUALITIES

The wine can be spoiled by microorganisms. There are three stages which could contribute to the spoilage of wine by microorganisms (Sponholz, 1993). These stages are (1) contamination of raw material with molds, yeasts, acetic acid bacteria or lactic acid bacteria; (2) During fermentation, the wild yeast or microorganisms from the winery equipment may spoil the wine; (3) During storage, when various microorganisms can grow and spoil the wine. The role of film yeasts, which are developed in wine stored in barrels as a result of aerobic growth of *Saccharomyces cerevisiae*, *Pichia*, *Hansenula* and *Brettanomyces* species has been discussed in detail (Baldwin, 1993). Some of the factors that are known to influence the susceptibility of wine to microbial spoilage are summarized as acidity, sugar content, alcohol content, accessory growth elements, tannin concentration, storage temperature, air availability (Joshi *et al.*, 1999). According to Amerine *et al.* (1980), by taking all the precautions, the microbiological qualities of the wine could effectively be maintained.

2.6 SENSORY QUALITIES

Appearance, colour, aroma, taste and subtle taste factors such as flavour of wine constitute the quality (Amerine *et al.*, 1980). Gayon (1978) observed that aroma and taste of wines was very complex and depended on a number of factors such as cultivars, agricultural land, vinification practices, fermentation and maturation. Sensory qualities particularly flavour sensation by palate is limited to sweetness, sourness, bitterness and astringency together with such taste as metallic and pungency in wine (Piggot *et al.*, 1990). Beelman and Mcardle (1974) and Carroll, 1986) reported that carbonic macerated young wines were softer tasting and possessed a special "Spicy" odour not present in wines made by traditional methods. A "cooked" or "dried fruit like" odour was also present, but a cinnamon like odour was predominating. There are certain flavour and quality differences due to holding of grapes under anaerobic conditions (Amerine and Doughlas, 1974). Therefore, wines resulting from carbonic maceration have a distinct aroma in which vague fruity notes predominate as a consequence of the anaerobic metabolism of grapes (Flanzy *et al.*, 1990). Carbonic maceration may also suppress the varietal aroma of some grape cultivars such as 'Concord' or enhance the expression of varietal aromas, such as 'Syrah' and 'Marechal Foch'. Another favourable feature of carbonic maceration is the early maturity characters of wine (Jackson, 1999). Thermovinified young red wines were found to be less harsh and astringent (Zoecklein *et al.*, 1995).

Phenolic compounds are very important for improving the sensory qualities like astringency, bitterness and colour which increased as a linear function of concentration as tannic acid in red wine (Robichaud and Noble, 1991). Sensory evaluation indicated that a wine from highly aerated culture had a lower score, possibly due to products of oxidative metabolism than the wine obtained by addition of ammonium nitrogen (Tzvetanov *et al.*, 1982).

2.6.1 Flavour profiling

Williams (1975) and Meilgard *et al.* (1979) applied quantitative descriptive analysis (QDA) to a variety of beverages like wine, cider beer to profile their flavour analytically. They observed that out of 86 descriptors used, 33 descriptors have greatest meaning to characterize the wine. Twenty eight pinot noir wines differed significantly for sensory attributes (Guinard and Cliff, 1987). At a simple level, a number of general descriptors can be used such as fruity, acidity, sweetness, astringency, alcohol, body, bitterness and sulphury (William, 1975 and Meilgard *et al.*, 1979). As many as 45 descriptors for evaluating the flavour profile of apple wine were reported (Joshi, 1997).

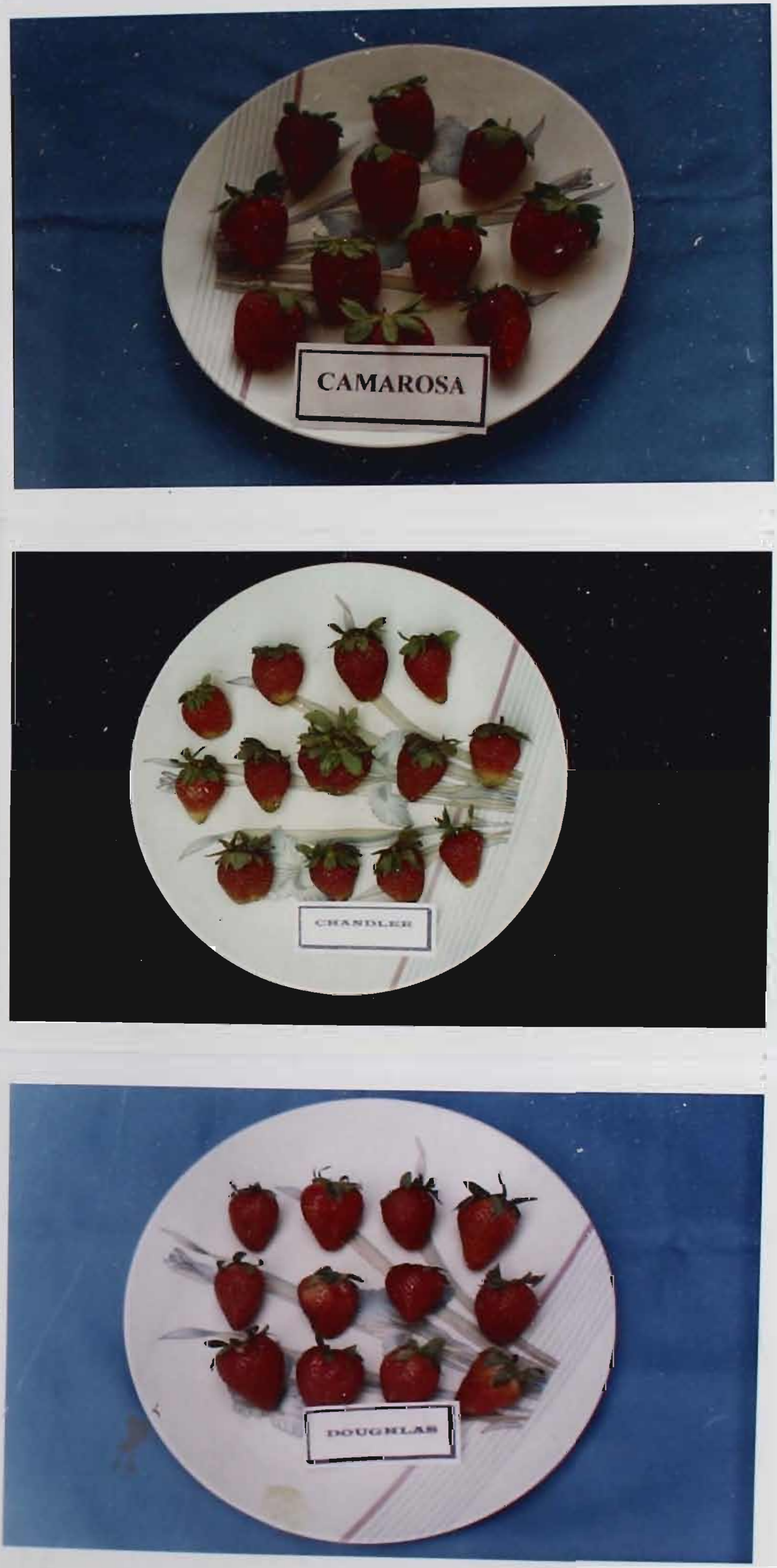


Plate 3.1. Comparison of different cultivars of strawberry

Chapter 3

MATERIALS AND METHODS

This chapter covers the detailed methods and techniques used to prepare and evaluate the wines from different strawberry cultivars. The present investigations were carried out in the Department of Postharvest Technology, Dr Y.S.Parmar University of Horticulture & Forestry, Nauni, Solan during the year 1998-2000. The materials used, methods and analytical techniques employed have been described under the following heads:

3.1 MATERIALS

3.2 EXPERIMENTAL

3.3 ANALYSES

3.1 MATERIALS

Fruits

Three cultivars of strawberry were obtained from different places. Chandler cultivar obtained from the Department of Pomology, Dr Y.S.Parmar University of Horticulture & Forestry, Nauni. Camarosa from Chandigarh fruit market and Doughlas from Una (Plate 3.1).

Wine yeast culture

The culture of *Saccharomyces cerevisiae* var. *ellipsoideus* strain UCD 595 used in the study was obtained from the Department of Enology and Viticulture, California, Davis, USA. It was maintained on yeast malt extract agar medium and recultured after every three months or whenever needed from the stock yeast culture

Fermented sugar

Sugar used to ameliorate the must for wine preparation was procured locally.

Enzyme

The pectinestrase enzyme used was manufactured by M/s Triton Chemical, Mysore, India, under the brand name of 'Pectinol'.

Carbonic maceration tank

The carbonic maceration tank was got manufactured by Regional Facility Centre, Chambaghat, Solan (H.P).

3.2 EXPERIMENT

Evaluation of strawberry cultivar for wine making

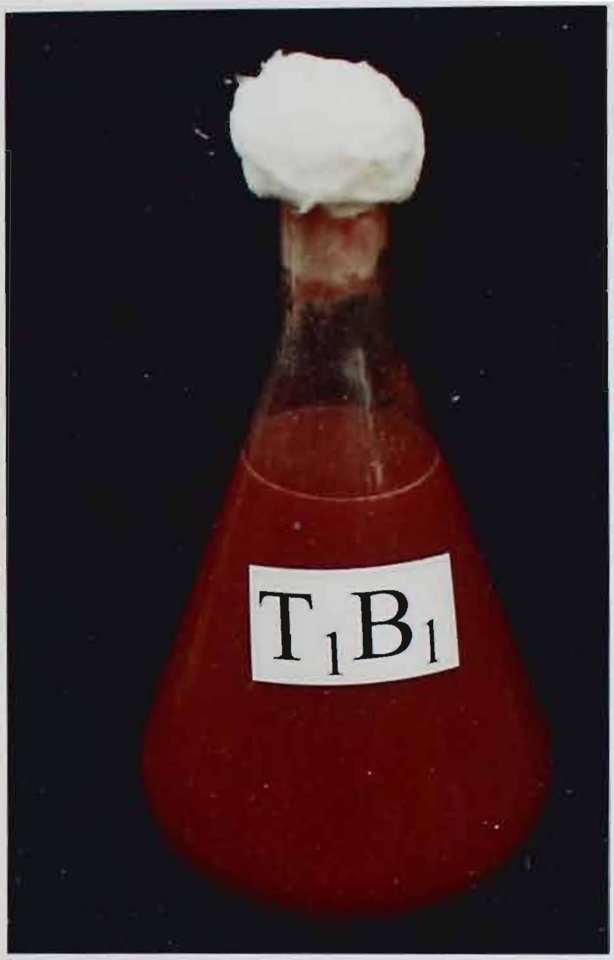
Fruits of three cultivars of strawberry detailed earlier were used to prepare must. Prior to pulping or must preparation, fruits were analysed for physico-chemical characteristics.

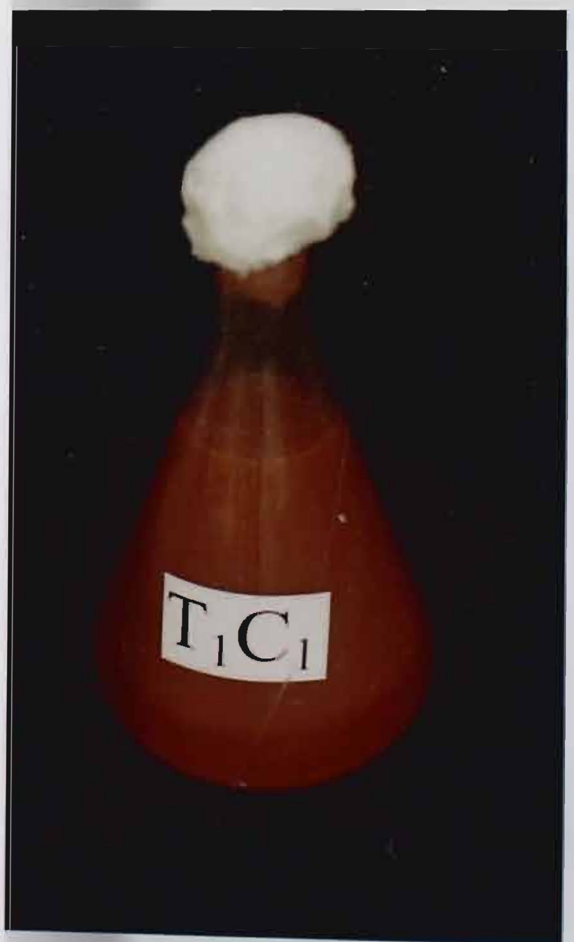
Preparation of wine

The wines were prepared by four different methods as shown in Plate 3.2 to 3.5 and depicted in Fig. 3.2.1. Total soluble solids, DAHP, pectinol and SO_2 as potassium metabisulphite concentration were constant in all the treatments. In all the cases, the pulp was diluted with 50% water, raising initial TSS to 24°B with sugar syrup 70°B, adding pectinol and diammonium hydrogen phosphate (DAHP) at the rate of 0.5 and 0.1 per cent, respectively. To each treatment, 50 ppm SO_2 in the form of potassium metabisulphite was added during fermentation and 50 ppm was added later, on completion of fermentation.

Control wine

The berries were destemmed and crushed with added SO_2 (50 ppm) and the pulp was diluted with 50% water and fermentation was carried out at a temperature





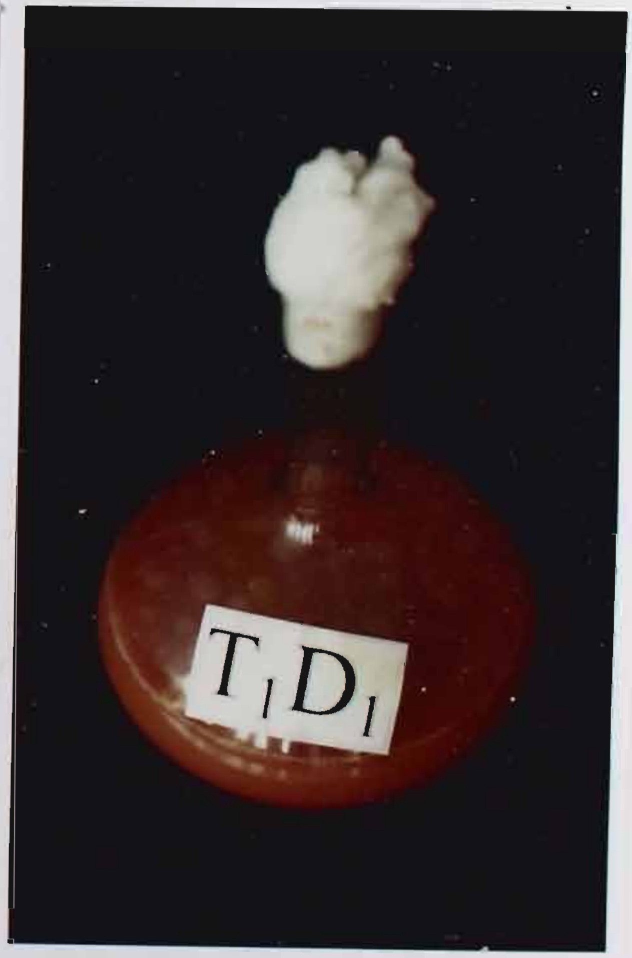


Plate 3.2. Comparison of control treatment of different cultivars musts

T_1B_1 – Camarosa T_1C_1 – Chandler T_1D_1 – Doughlas

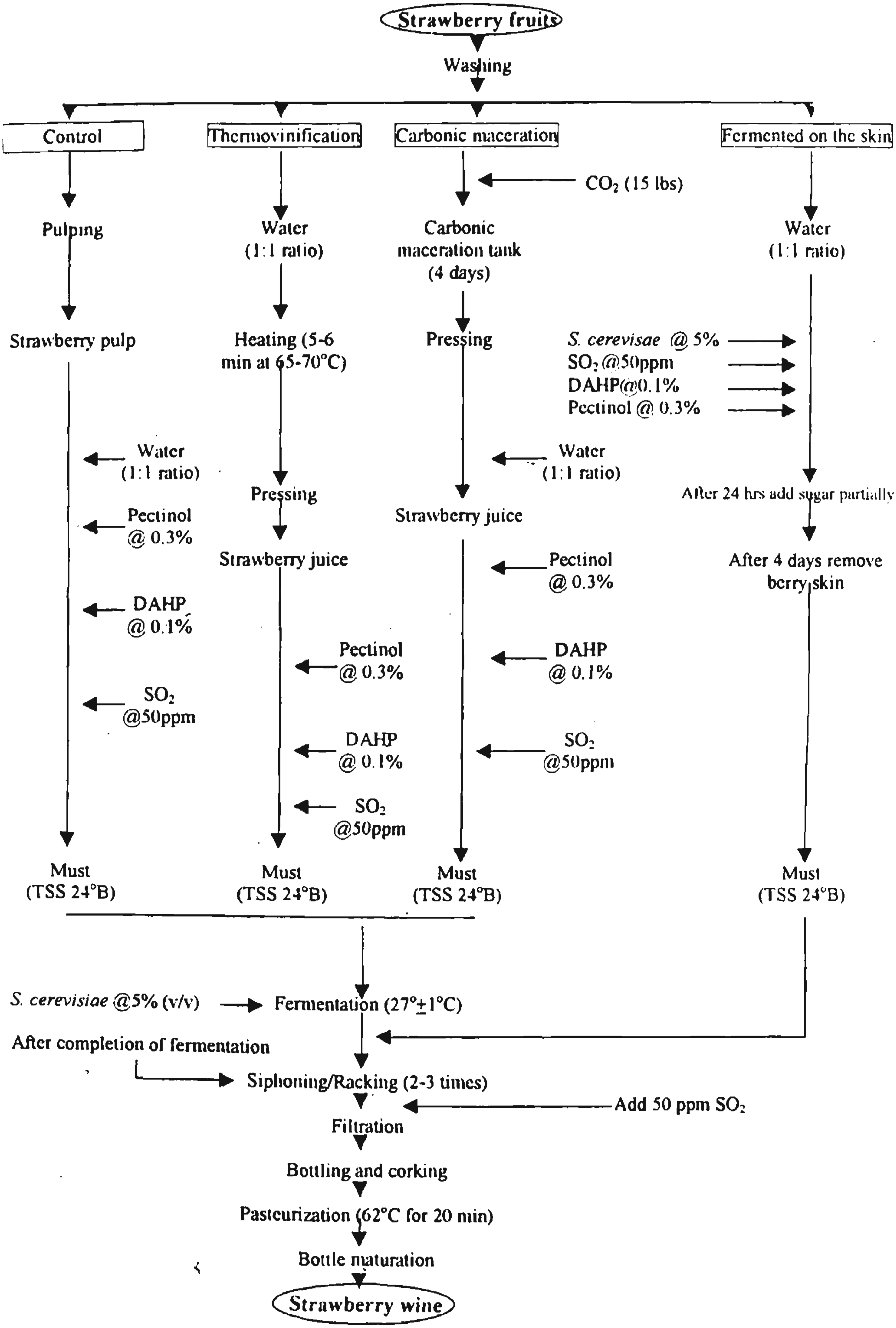


Fig. 3.2.1: Flowsheet of the treatments used for the preparation of *Strawberry Wine*

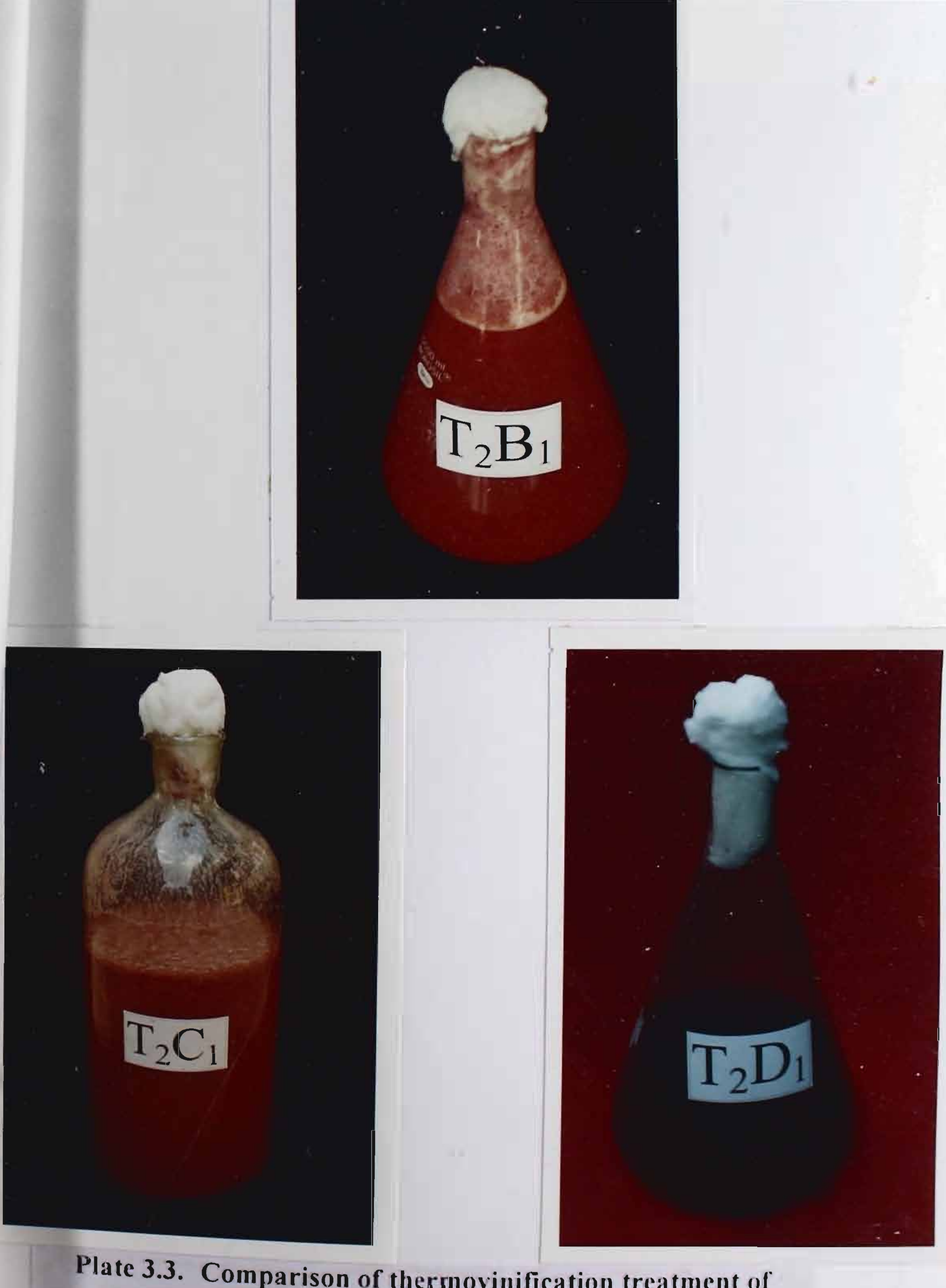


Plate 3.3. Comparison of thermovinification treatment of different cultivars musts
T_2B_1 – Camarosa T_2C_1 – Chandler T_2D_1 – Doughlas

of 27 ± 1°C as shown in Plate 3.2 in 5 litre flasks, fitted with air locks and initiated by addition of active yeast culture of Saccharomyces cerevisiae var. ellipsoideus at the rate of 5 per cent. When there was no further loss in TSS, the fermentation was considered as completed. Air locks were fitted in the mouth of glass bottle near the end of fermentation. It was followed by siphoning/racking and filtration.

Thermovinification of wines

Berries were destemmed and washed. The berries were heated at 65-70°C in 50% water for 5-6 minutes. The free run juice was collected and must was prepared by addition of above written compounds. The SO_2 in the form of potassium metabisulphite was added at the rate of 50 ppm. The must was kept overnight before inoculation with the active yeast culture. Fermentation was carried out as discussed earlier and shown in Plate 3.3.

Carbonic maceration

Carbonic maceration of the whole berries was done in 10 litre stainless steel carbonic maceration tank (Plate 3.6). The whole berries of selected cultivars was filled into a tank. The tank was sealed and flushed thoroughly for 10 min. with CO_2 gas introduced by a line to the bottom of the tank. After flushing, CO_2 pressure in the tank was adjusted to about 15 lbs to ensure a good seal and anaerobic conditions. Tank was held at 27°C for the duration of the treatment. Gas production within the tank, as evidenced by increasing gauge pressures was observed within 36-48 hrs. after sealing the tank. Excess pressure was released from the tank several times daily by manually opening the valves. To terminate carbonic maceration after 4 days, the pressure was released from a tank and the berries were removed as shown in Plate 3.6. The berries were crushed and pressed in a basket press. The juice was diluted with 50% water and the must was prepared by addition of sugar syrup of 70°B DAHP, pectinol and potassium metabisulphite in same concentration as discussed earlier.

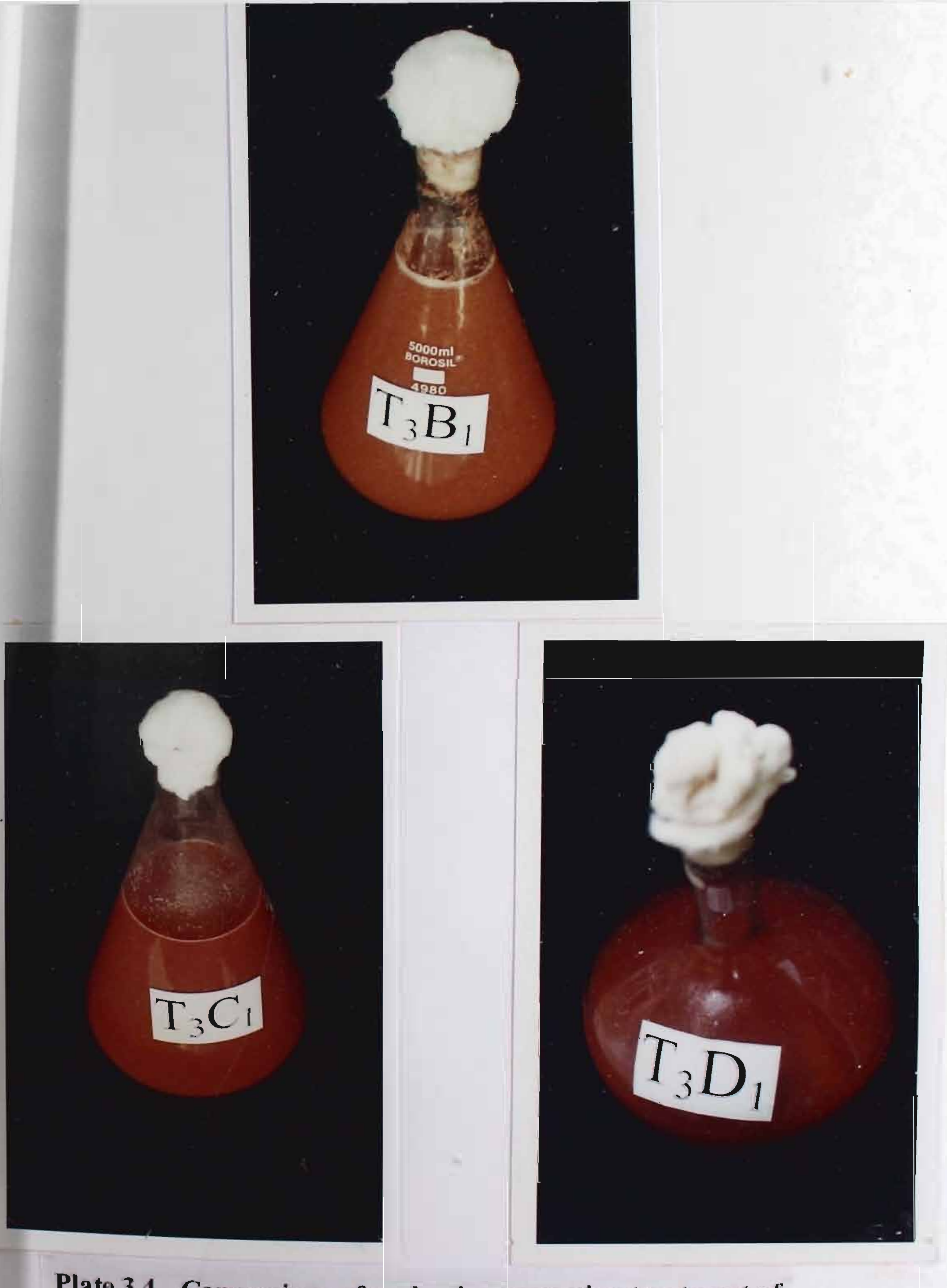


Plate 3.4. Comparison of carbonic maceration treatment of different cultivars musts
T_3B_1 – *Camarosa* T_3C_1 – Chandler T_3D_1 – Doughlas

Fermentation on the skin

The berries were washed, destemmed and 50% water was added and placed in 5 litre glass flask. SO_2 50 ppm, DAHP and yeast strain was added. After 24 hours, active yeast strain was added and initial TSS was raised to 24°B. The berries were kept for 4 days as shown in Plate 3.5. Then,the pressed juice was fermented to dryness at 27°C under air locks. In all the treatments, fermentation was initiated by addition of active yeast culture of *Saccharomyces cerevisiae* var. *ellipsoideus* at the rate of 5%. When there was no loss of TSS, the fermentation was considered as completed. Air locks were fitted in the mouth of glass flasks near the end of fermentation. It was followed by siphoning/racking and filtration. All the wines were racked initially after every 15 days and then, after one month. During fermentation, fall in TSS (°B), titratable acidity and ethanol concentration were monitored at appropriate intervals of time. The prepared strawberry wines were filled in clean glass bottles upto the brim adding 50 ppm potassium metabisulphite.

3.3 ANALYSES

Physico-chemical characteristics

Strawberry fruits of different cultivars were analyzed for physico-chemical characteristics viz. weight, length, diameter, skin colour, TSS, titratable acidity, reducing sugar and total sugars. Ten fruits of each cultivar were taken and analysed.

Must

Musts of three cultivars were analysed for TSS, titratable acidity and colour prior to fermentation.

Wine

Strawberry wines from different cultivars (Plate 3.7) and treatments (Plate 3.8) were analyzed for TSS, titratable acidity, ethanol, pH, colour, total phenols, total esters, fusel oil, total and reducing sugars, volatile acidity and anthocyanins. The analysis was performed prior, during and after every three months upto 9 months of maturation.

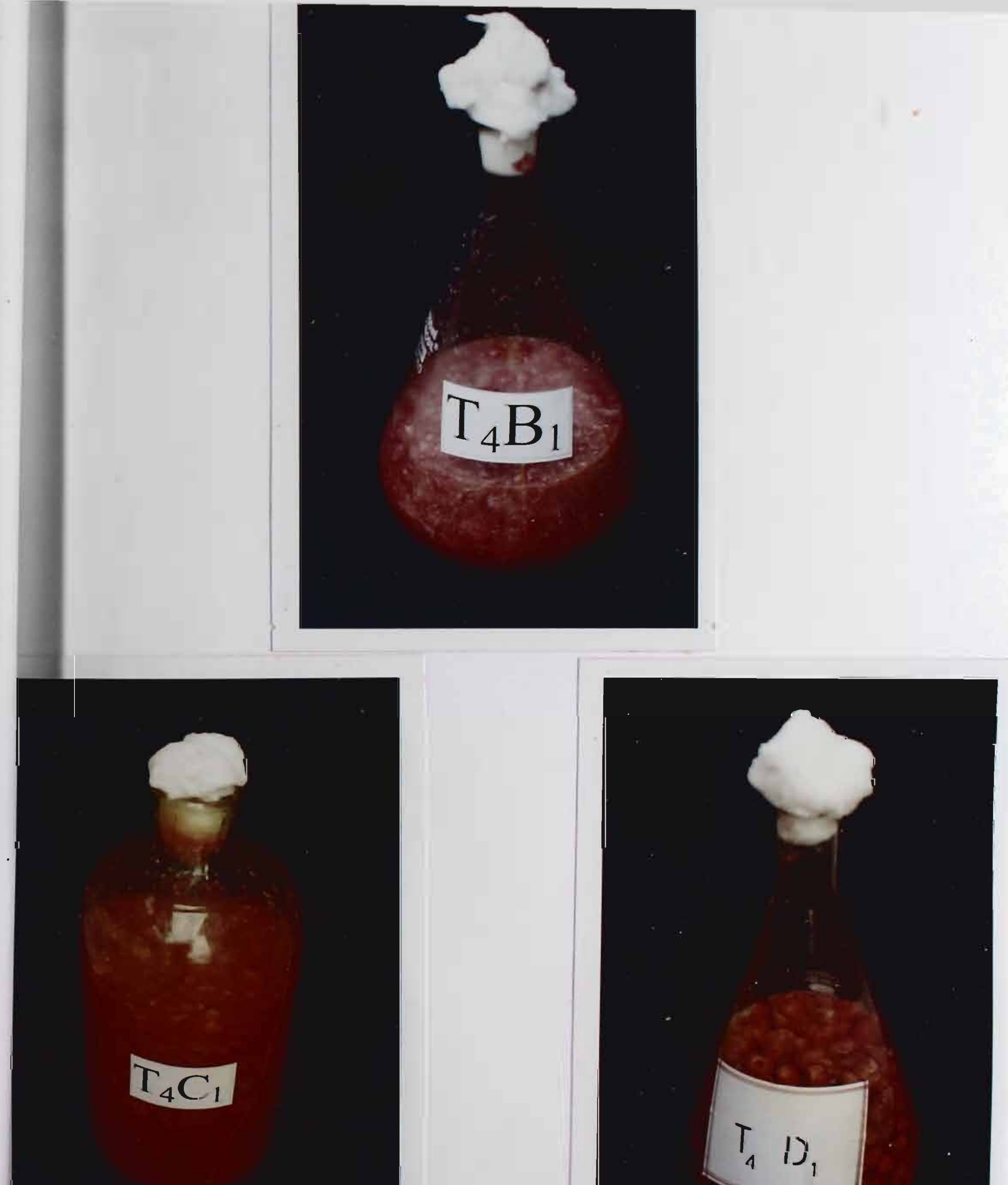


Plate 3.5. Comparison of fermented on the skin treatment of different cultivars musts
T_4B_1 – Camarosa T_4C_1 – Chandler T_4D_1 – Doughlas

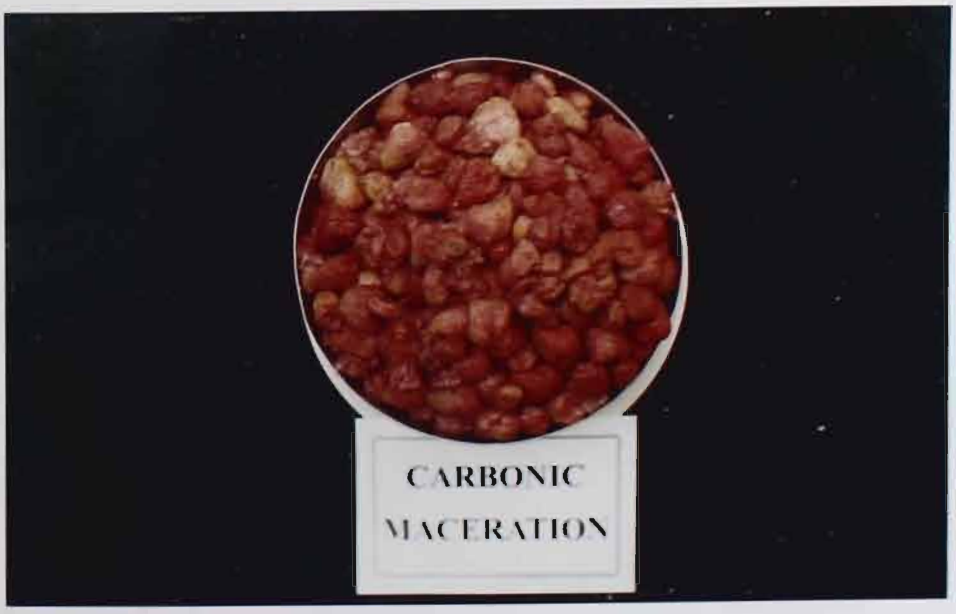


Plate 3.6. Carbonic maceration tank and carbonic macerated berries

Physico-chemical characteristics

a) Physical parameters

Weight, diameter and length

The weight of 10 fruits was taken with the help of physical balance while diameter and length were measured with the vernier calippers. The weight was expressed in gm while diameters and length were measured in cm. Five fruits were observed in each replication.

b) Chemical characteristics

Total soluble solids

Total soluble solids (TSS) were measured using Erma hand refractometer (0 to 32°B). The results were expressed as degree Brix (°B). The readings were corrected by applying the correction factor for the temperature variation (A.O.A.C., 1980).

Titratable acidity

Titratable acidity was estimated by treating a known aliquot of the sample against N/10 NaOH solution using phenolphthalein as an indicator. Wines were diluted appropriately followed by similar titration. The titratable acidity was calculated and expressed as per cent citric acid (A.O.A.C., 1980) as detailed below:

$$\text{Per cent titratable acidity (citric acid)} = \frac{VxNx64x100}{vx1000}$$

where:

V = Volume of NaOH used for titration

N = Normality of NaOH solution

v = Volume of sample solution

Plate 3.7. Comparison of strawberry wines from different cultivars

pH

The pH was taken with ELTOP-3030 pH meter prior to pH measurement, the instrument was standardized with buffer solutions of pH 4 and 7

Colour

Lovibond Tintometer model E was used to measure the colour of the wine using one inch cell. The colour was expressed as red, yellow and blue units (Ranganna, 1986).

Total and reducing sugars

The total and reducing sugars were estimated by Lane and Eynon's volumetric method (A.O.A.C., 1980) by titrating a known aliquot of sample against Fehling's solution (before and after hydrolysis). The total sugars estimated were expressed as percentage.

Alcohol

Ethyl alcohol in the finished wines was determined by colorimetric method (Caputi *et al.*, 1968). One ml wine with 30 ml of distilled water was distilled into 25 ml potassium dichromate solution. The optical densities of the samples as well as standard were taken at a wavelength of 600nm in a colorimetric against a blank. The amount of ethanol present in the samples was determined from the standard curve, prepared similarly.

Volatile acidity

Volatile acidity was determined by the standard method (Amerine *et al.*, 1980). The distillate was titrated with 0.025 N NaOH and the volatile acidity was expressed as acetic acid (g/100 ml).

$$\text{Acetic acid} = \frac{VxNx60x100}{1000(v)}$$

Plate 3.8. Comparison of strawberry wines from different treatments

Where,

V = Volume of NaOH used for titration

N = Normality of NaOH solution

v = Sample volume (ml)

Total phenols

The total phenols or tannin contents in different fruit wines were determined by the Folin-Ciocalteu procedure given by Singleton and Rossi (1965) in which the absorbance was measured at 765 nm in colorimeter against a blank. A standard calibration curve of tannic acid using its different concentrations was prepared from which the tannin contents were estimated in different wines.

Total esters

Total esters were determined in wine as per the method of Liberaty (1961). A standard calibration curve of ethyl acetate using its different concentrations was prepared. The ester contentsin the wine were estimated from the standard curve preparation. The absorbance of both the standards and samples was taken at 510 nm in a colorimeter against a blank.

Fusel oil

Fusel oil in wine was estimated by the method given by Guymon and Nakagiri (1952). A standard calibration curve of fusel oil standard using its different concentrations was prepared. The quantity of fusel oil contents present in the samples was estimated from the standard curve. The optical density of the sample as well as standard were taken at 530 nm against a blank i.e. concentrated sulfuric acid. The results were expressed as fusel oil mg/100 ml.

Anthocyanins

Anthocyanins in wines were measured by the method given by Harborne (1973). One ml of wine was taken in 16 ml of acidic methanol (containing 1% hydrochloric acid). The contents were allowed to stay overnight at 4°C. Thereafter absorbance was recorded at 530 nm on spectronic-20 colorimeter. A blank was also run simultaneously for calibration of zero absorbance. Anthocyanin content was expressed in terms of absorbance units at 530 nm (A-530 nm) per ml of wine.

c) Identification of phenols by TLC

Preparation of samples for TLC

Thirty ml of the sample of wine was concentrated to 1 ml in a boiling water bath at a temperature of 65°C. Later on methanol was added to 1 ml of wine sample and dissolved the insoluble phenolic precipitates by centrifuging the sample. Then the spots were developed on the TLC plates using a micro-pipette. The plates were kept for 5 min. for drying the spots. The chromatogram was run with a solution of 9:1:1 ethyl acetate : acetic acid : water mixture (Ranganna, 1986). Further spot development and identification was carried out.

Separation and identification of types of phenols

Phenolics in the different wines were separated and identified by the TLC. Silica gel-G 20 gm was taken in an Erlenmyer's flask to which 45 ml distilled water was added. The flask was shaken vigorously for 30 seconds thereafter the slurry was transferred to plates. The uniform thickness of the plates was 0.25 mm. These plates were then allowed to dry in the air. The plates were activated in an oven at 110°C for two hours. Spotting and developing of the plates was practised as given by Bishara *et al.* (1972) and described by Ranganna (1986). The different phenols were identified by taking RF (Resolution front) value of spots and colour developed on the plates. Some spots were identified after spraying solution of ferric chloride, potassium ferric cyanide. The samples were examined in UV light. Tannic acid solution was run to confirm its RF values in TLC plates.

$$\text{Resolution front} = \frac{\text{Distance travelled by the sample}}{\text{Distance travelled by solvent front}}$$

tested in comparison to the standard whose intensity was rated to be the highest with the score of standard for each descriptor was provided to the judges as given in the Table 3.1. The proforma used for the evaluation is given in the ANN-II

Table 3.1. Standards used for flavour profiling

Vegetative	Shredded cabbage
Alcoholic	8% ethyl alcohol
Vinegary	Vinegar diluted 25 times
Earthy	0.5% bentonite solution
Spicy	Spices extract
Sweety	2% sugar solution
Sour	8% citric acid solution
Bitter	Tea leaves extract
Astringency	Aonla extract
Yeasty	Fermenting must
Phenolic	100 mg/l solution of tannic acid
Strawberry jam like	Strawberry jam
Fusel alcohol like	1% propyl alcohol
Berry like	Strawberry essence

g) Statistical analysis of data

Analysis of variance

The data of quantitative estimation of various physico-chemical characteristics of different cultivars of wines were analysed by Completely Randomized Design (CRD), while the data of sensory evaluation, analysed by the Randomized Block Design (RBD) as described by O'Mahony (1985).

Principal component analysis

Principal component analysis has been used to detect the variation and linear relationship of whole system under study, without taking into account of the specific groups. This technique of Principal Component Analysis (PCA) was first described by *Karl Pearson (1901) but computing method come much* later from Hotelling (1933). The data of flavour profiling were first assessed by the analysis of variance (RBD) as per the standard practice used for the analysis of this type of data. Two factor analysis for wines and attributes was performed from the different values for analysis of variance F values were determined for significance and only the means of significant terms were retained for further analysis. The means were used for Principal Component Analysis (PCA) as per instructions given for this computer package, PCA, BAS (Ludwig and Reynolds, 1988). Various descriptors, treatments and their scores constituted the data. The output was obtained in the form of principal components (first three), correlation coefficients, matrix and Eigen vectors. The analysis was performed without rotation, the interpretation of data from PCA was made by plotting principal components PC-1 Vs PC-2 or PC-1 Vs PC-3 and attributes loading as vectors alongwith treatments simultaneously.

Chapter 4

RESULTS AND DISCUSSION

The investigations entitled "**Preparation and Evaluation of Strawberry Wine**" were conducted in the Department of Postharvest Technology, Dr Y.S.Parmar University of Horticulture & Forestry, Nauni, Solan. The results obtained are discussed in this chapter under the following heads:

4.1 PHYSICO-CHEMICAL EVALUATION OF FRESH STRAWBERRY FRUITS OF DIFFERENT CULTIVARS

4.2 FERMENTATION BEHAVIOUR, PHYSICO-CHEMICAL AND SENSORY EVALUATION OF STRAWBERRY WINES OF DIFFERENT CULTIVARS PREPARED BY DIFFERENT METHODS

4.3 DETERMINE CHANGES OCCURRING IN WINES DURING MATURATION

4.4 ECONOMIC EVALUATION OF THE STRAWBERRY WINE PRODUCTION

4.1 PHYSICO-CHEMICAL EVALUATION OF FRESH STRAWBERRY FRUITS OF DIFFERENT CULTIVARS

4.1.1 Physico-chemical characteristics of different strawberry cultivars

Physical

The results on physical characteristics of strawberry fruits (Table 4.1.1) show that all the cultivars differed significantly among themselves for diameter, weight, length and pulp recovery. The highest weight (17.01 gm) was found in Camarosa and lowest in Doughlas (12.02 gm). Perusal of the data further revealed that this cultivar also had the highest fruit diameter, length and pulp content. Irrespective of the cultivar, the pulp content of fruits from all the cultivars was more than 90 per

Table 4.1.1 Physico-chemical characteristics of different strawberry cultivars

Cultivar	Weight (gm)	Diameter (cm)	Length (cm)	TSS (°B)	Titratable acidity (% CA)	pH	Total sugar (%)	Reducing sugar (%)	Pulp (%)	Remarks
Camarosa	17.01	3.66	4.78	9.0	0.76	3.29	6.6	5.0	97	Fruits larger and firmer almost cylindrical and conic, external colour wine red and internal darker red
Chandler	13.30	3.16	3.88	7.3	0.82	3.19	5.8	4.9	96	Fruits large, long conic, skin glossy, external colour cardinal red with internal medium red
Doughlas	12.02	2.76	3.48	7.0	0.79	3.26	5.7	4.3	94	Fruits smaller, flesh colour darker red
CD($P \geq 0.05$)	1.12	0.210	0.241	0.988	NS	0.080	0.758	0.584	1.14	

with Doughlas cultivar. The total sugars were present in the range between 5.7 to 6.6 per cent, whereas reducing sugars were recorded in the range 4.3 to 5.0 per cent and were in confirmation to those reported earlier (Green, 1971; Kim *et al.*, 1993). The highest total and reducing sugars (6.6 and 5.0%) were recorded in Camarosa and lowest (5.7 and 4.3%) in Doughlas. The total sugar content of the fruit is considered as the most important criterion for selecting suitable fruit cultivars for wine preparation (Amerine *et al.*, 1988; Sandhu and Joshi, 1995). However, for the strawberry fruit the total sugars are too low for fermentation into a table wine (10-11% v/v) alcohol. Therefore, ameliorating the must to provide fermentable sugar is a pre-requisite for preparation of wine as practised for other stone fruits (Amerine *et al.*, 1980; Vyas and Joshi, 1982; Joshi, 1997).

On the basis of fruit weight, diameter, pulp content, Camarosa cultivar seems to have an edge over other cultivars with respect to the characteristics desirable for conversion into wine. Based on the overall results on physico-chemical analysis of strawberry fruit cultivars, it can be stated that Camarosa cultivar possess many desirable characteristics like highest diameter, weight, length, total sugar, optimum acidity, reducing sugar and pulp followed by Chandler and Doughlas to prepare wine.

4.2 FERMENTATION BEHAVIOUR, PHYSICO-CHEMICAL AND SENSORY EVALUATION OF STRAWBERRY WINES OF DIFFERENT CULTIVARS PREPARED BY DIFFERENT METHODS

4.2.1 Changes in strawberry musts during fermentation

Fermentability of different cultivar musts

The results (Fig. 4.2.1) depicted the fermentation behaviour of 3 different strawberry musts. In general, at the initial stages (upto 48 hrs), the musts of all the cultivars witnessed a fast reduction in TSS. Doughlas must recorded the highest reduction in TSS followed by Chandler. Till 96 hours, the pattern remained the same, but after 144 hours, it changed clearly with the flattening of curve followed by cent. The colour of fruits of all the cultivars was red. Kotecha and Madhavi (1995) reported that berries ready for harvest should be fully red or pink. Since the colour of strawberries was red, so it can be stated that berries have attained proper maturity. It is clear based on physical parameters that the fruits had been harvested at proper maturity.

Chemical

The results (Table 4.1.1) on the chemical characteristics of strawberry cultivars showed that Camarosa was significantly different from Chandler and Doughlas in TSS while Chandler and Doughlas were at par with each other. The highest TSS (9.0°B) was recorded in Camarosa and lowest (7.0°B) in Doughlas. Further, all the cultivars had TSS within the range of 7.0-9.0°B. Almost similar values for TSS of strawberry cultivars have been reported earlier (Kotecha and Madhavi, 1995). There was not significant difference among the cultivars for titratable acidity with highest acidity (0.82% C.A.) in Chandler and lowest (0.76% C.A.) in Camarosa. A comparison of the values for acidity with those reported earlier revealed that our results are different with respect to both the lower and higher values (Green, 1971; Kader, 1991). The differences might be due to the different agroclimatic conditions as well as the type of cultivars. The titratable acidity is an important characteristic of the fruits due to its effect on taste (Wills *et al.*, 1981). As compared to the other stone fruits like plum and apricot, the titratable acidity range is similar and thus, would require less dilution as practised for plum and apricot fruits for wine preparation (Vyas and Joshi, 1982; Joshi *et al.*, 1990).

All the cultivars differed significantly for their pH values (range 3.19 to 3.29). The trend in pH values corroborated with titratable acidity discussed earlier. Nevertheless, the pH of all the cultivars remained within the acidic range required for effective alcoholic fermentation (Amerine *et al.*, 1980).

The results on total and reducing sugar revealed that different cultivars were significantly different among themselves. But Chandler cultivar was found at par with Doughlas cultivar. The total sugars were present in the range between 5.7 to 6.6 per cent, whereas reducing sugars were recorded in the range 4.3 to 5.0 per cent and were in confirmation to those reported earlier (Green, 1971; Kim *et al.*, 1993). The highest total and reducing sugars (6.6 and 5.0%) were recorded in Camarosa and lowest (5.7 and 4.3%) in Doughlas. The total sugar content of the fruit is considered as the most important criterion for selecting suitable fruit cultivars for wine preparation (Amerine *et al.*, 1988; Sandhu and Joshi, 1995). However, for the strawberry fruit the total sugars are too low for fermentation into a table wine (10-11% v/v) alcohol. Therefore, ameliorating the must to provide fermentable sugar is a pre-requisite for preparation of wine as practised for other stone fruits (Amerine *et al.*, 1980; Vyas and Joshi, 1982; Joshi, 1997).

On the basis of fruit weight, diameter, pulp content, Camarosa cultivar seems to have an edge over other cultivars with respect to the characteristics desirable for conversion into wine. Based on the overall results on physico-chemical analysis of strawberry fruit cultivars, it can be stated that Camarosa cultivar possess many desirable characteristics like highest diameter, weight, length, total sugar, optimum acidity, reducing sugar and pulp followed by Chandler and Doughlas to prepare wine.

4.2 FERMENTATION BEHAVIOUR, PHYSICO-CHEMICAL AND SENSORY EVALUATION OF STRAWBERRY WINES OF DIFFERENT CULTIVARS PREPARED BY DIFFERENT METHODS

4.2.1 Changes in strawberry musts during fermentation

Fermentability of different cultivar musts

The results (Fig. 4.2.1) depicted the fermentation behaviour of 3 different strawberry musts. In general, at the initial stages (upto 48 hrs), the musts of all the cultivars witnessed a fast reduction in TSS. Doughlas must recorded the highest reduction in TSS followed by Chandler. Till 96 hours, the pattern remained the same, but after 144 hours, it changed clearly with the flattening of curve followed by

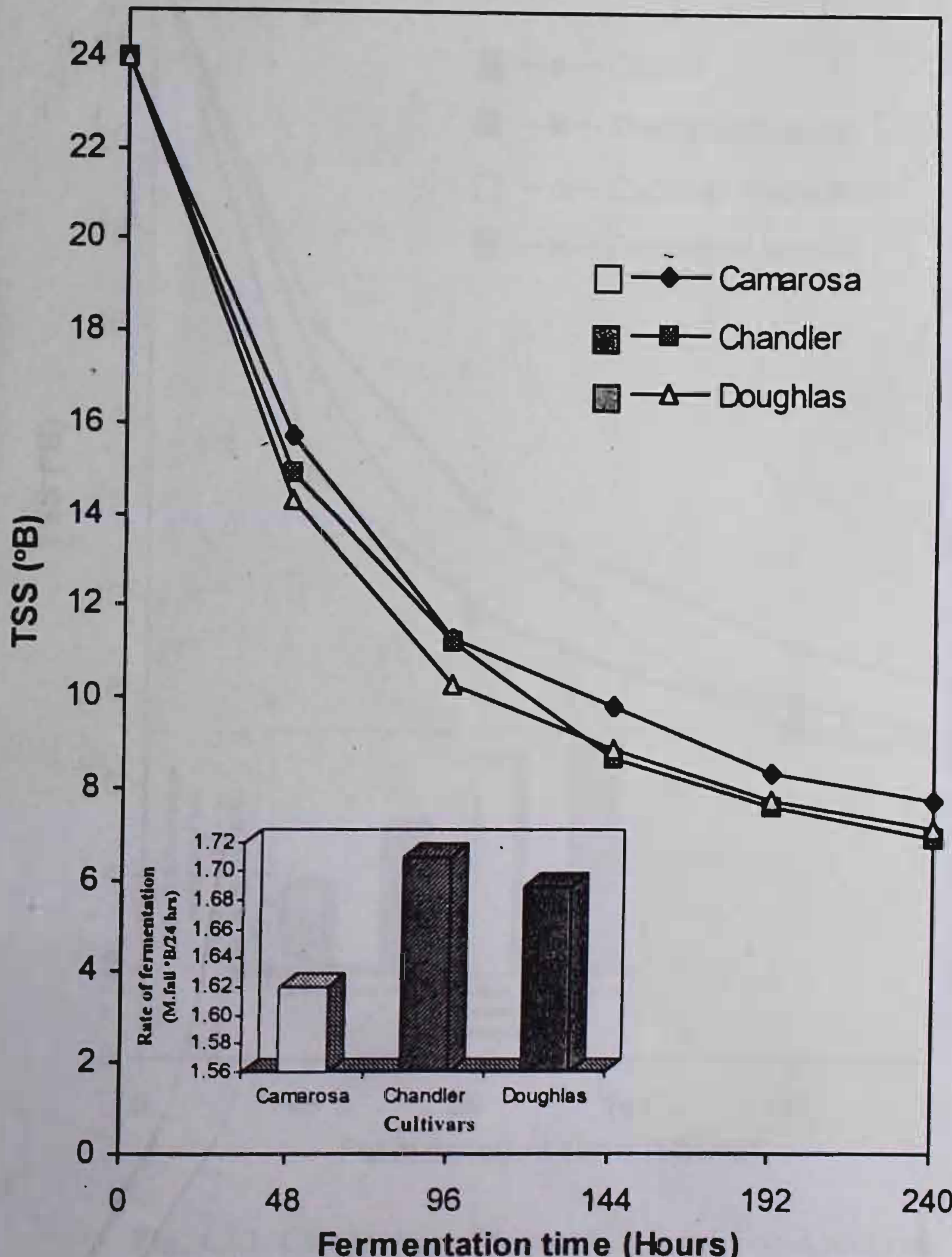


Fig. 4.2.1. Comparison of fermentation behaviour and rate of fermentation (RF) of different strawberry musts of different cultivars

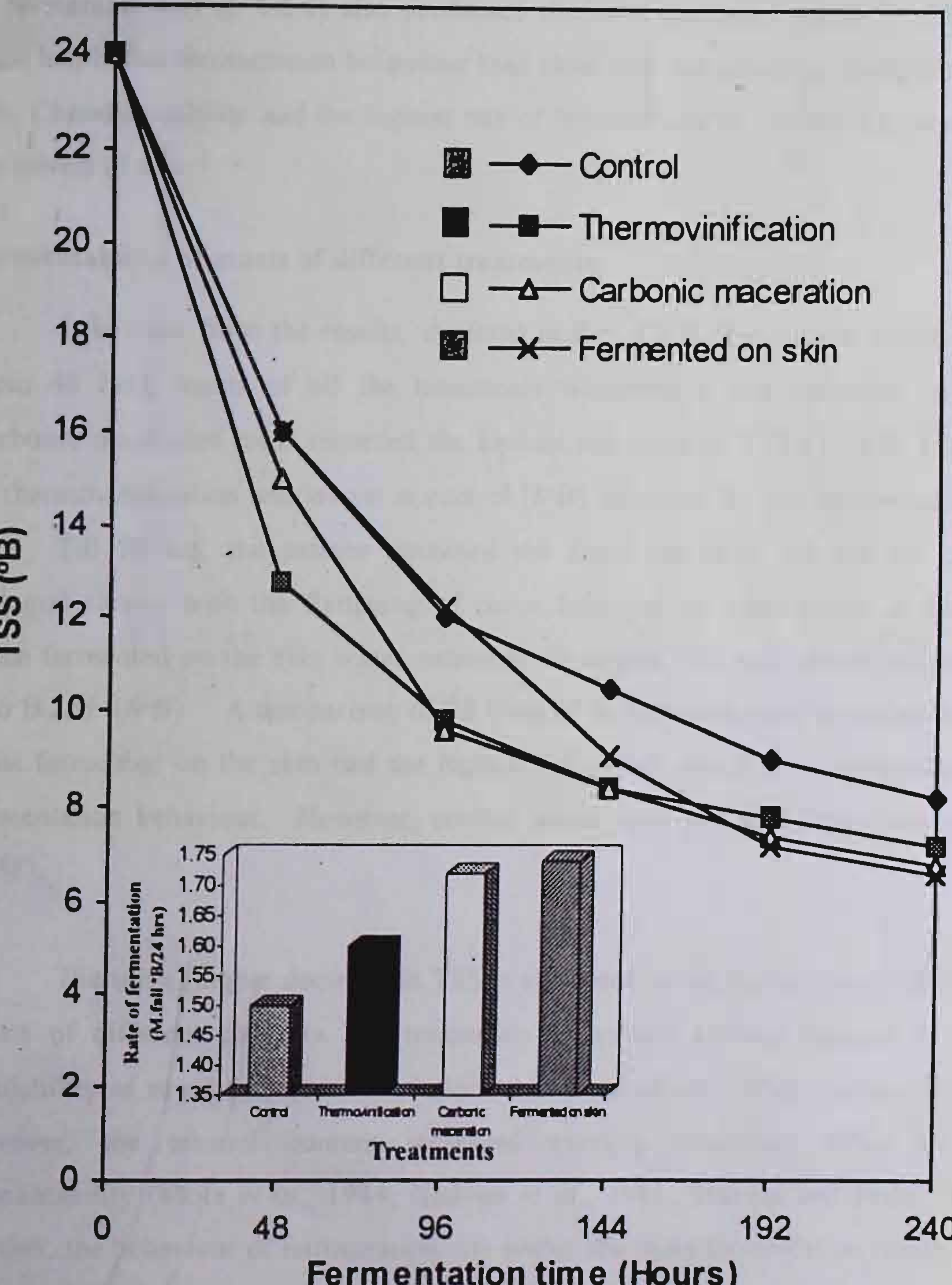


Fig. 4.2.2. Comparison of fermentation behaviour and rate of fermentation (RF) of strawberry musts of different treatments

stabilization at 240 hours, when Chandler cultivar recorded the lowest TSS (6.9°B) and highest (7.75°B) TSS in Camarosa cultivar was recorded. A comparison of rates of fermentation (Fig. 4.2.1) also confirmed the trend discussed earlier. Chandler must had better fermentation behaviour than other two cultivars. In confirmation to this, Chandler cultivar had the highest rate of fermentation (1.71) and Camarosa has the lowest (1.62).

Fermentability of musts of different treatments

It is clear from the results, depicted in Fig. 4.2.2 that in the initial stages (upto 48 hrs), musts of all the treatments witnessed a fast reduction in TSS. Carbonic macerated must recorded the highest reduction in TSS (11.2°B) followed by thermovinification and lowest in control (8°B) followed by that fermented on the skin. Till 96 hrs, the pattern remained the same but after 144 hrs the pattern changed clearly with the flattening of curve followed by stabilization at 240 hrs, when fermented on the skin wines recorded the lowest TSS and control the highest i.e. (6.6°B and 8.9°B). A comparison of RF (rate of fermentation) also revealed that the must fermented on the skin had the highest RF (1.74) which is in confirmation to fermentation behaviour. However, control wines have the least fermentation rate (1.58).

The initial higher decrease in TSS *is attributed to the higher fermentability of* musts of different cultivars and treatments (described earlier) because of more availability of sugar and lesser ethyl alcohol in the medium. With increase in time, however, the ethanol content increased exerting inhibitory effect on the fermentability (Mota *et al.*, 1984; Nishino *et al.*, 1985; Sharma and Joshi, 1996). Further, the behaviour of fermentation rate within the same fermentation condition is due to their individual varietal characteristics and imbalance in assimilable nitrogen and sugar content of must (Amerine *et al.*, 1980). Benard *et al.* (1971) reported that holding whole grapes under CO_2 pressure slows down fermentation and consequently, helps in preventing an undue rise in temperature.

Changes in ethanol

The changes in ethanol concentration of different must can be seen in Fig 4.2.3. As expected, with increase in time of fermentation, the ethanol content registered an increase in all the 3 cultivars. During different intervals of time change in ethanol content could be witnessed. A close examination of the curve revealed that the ethanol content of all the cultivars was of similar level. However, at the end of fermentation, Chandler recorded the highest (9.8%) ethanol and Camarosa the least (9.4%). These results are in conformity with their respective rate of fermentation and the fermentation behaviour discussed earlier.

The trend of ethanol increase or TSS fall during fermentation discussed earlier was similar to the fermentation of any fruit to make a wine (Amerine *et al.*, 1980; Joshi and Bhutani, 1990; Sharma and Joshi, 1996 and Joshi, 1999). However, the individual differences between the cultivars with respect to ethanol production might be due to differences in nutrient concentration effecting the fermentability, hence the ethanol production (Amerine *et al.*, 1980).

Among the treatments upto to 96 hours, there is a steep increase in ethanol concentration (Fig. 4.2.4). At 144 hrs thermovinified wines recorded the highest ethanol concentration (8.9%) followed by carbonic macerated wines those fermented on the skin and the control. At the end of fermentation, the control recorded lowest ethanol (9.4%) while that fermented on the skin had the highest ethanol content (10.2%). The results are in conformity with their respective mean fall of TSS, as described earlier.

4.2.2 Physico-chemical characteristics of wines

Total soluble solids, total sugars and reducing sugars

Table 4.2.1 summarizes the total soluble solids, total sugars and reducing sugars of different wines. It is revealed from the data that there were significant differences among the wines of different cultivars and treatments for TSS. The

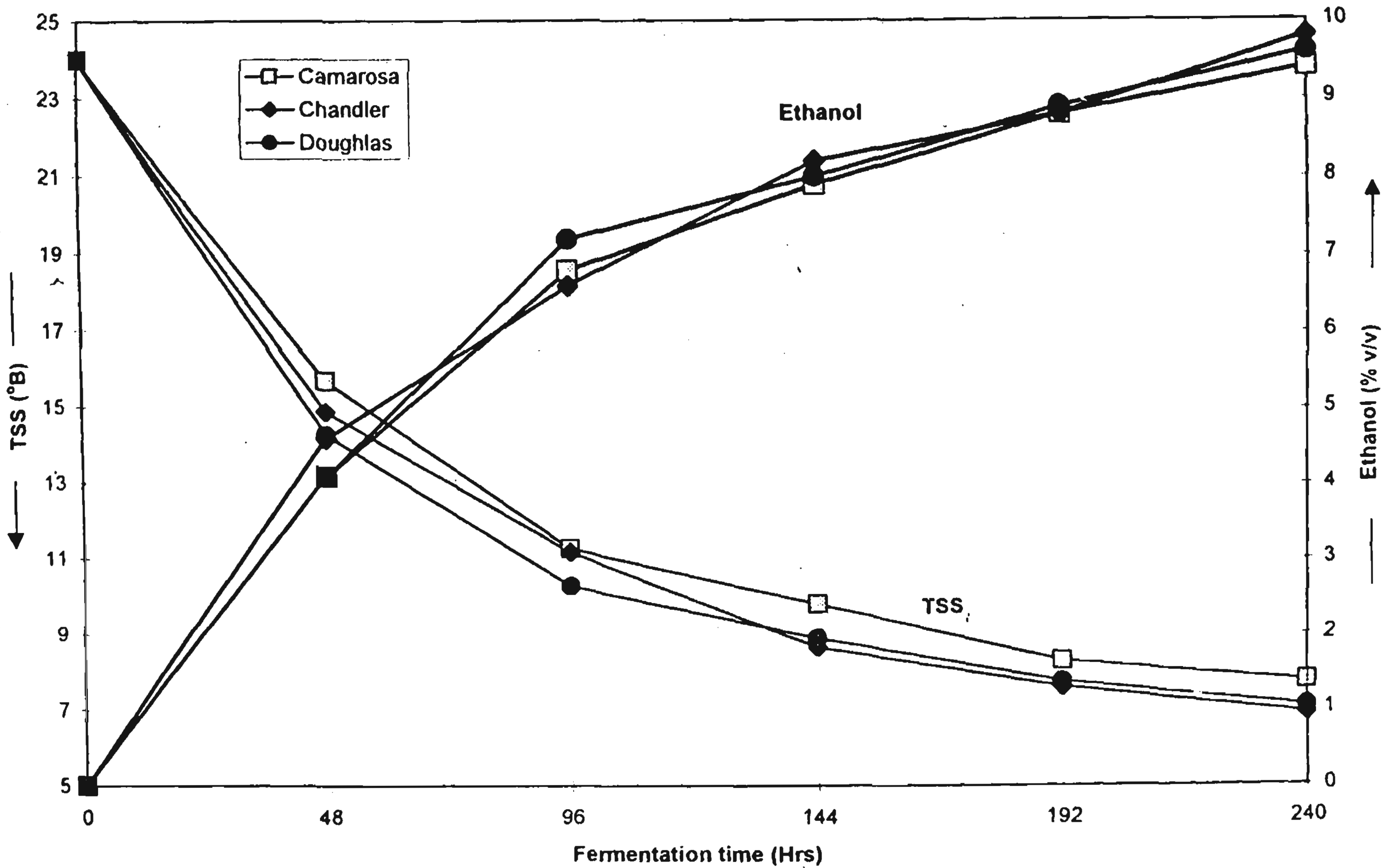


Fig. 4.2.3. Comparison of fermentation behaviour and ethanol production of different strawberry cultivar musts

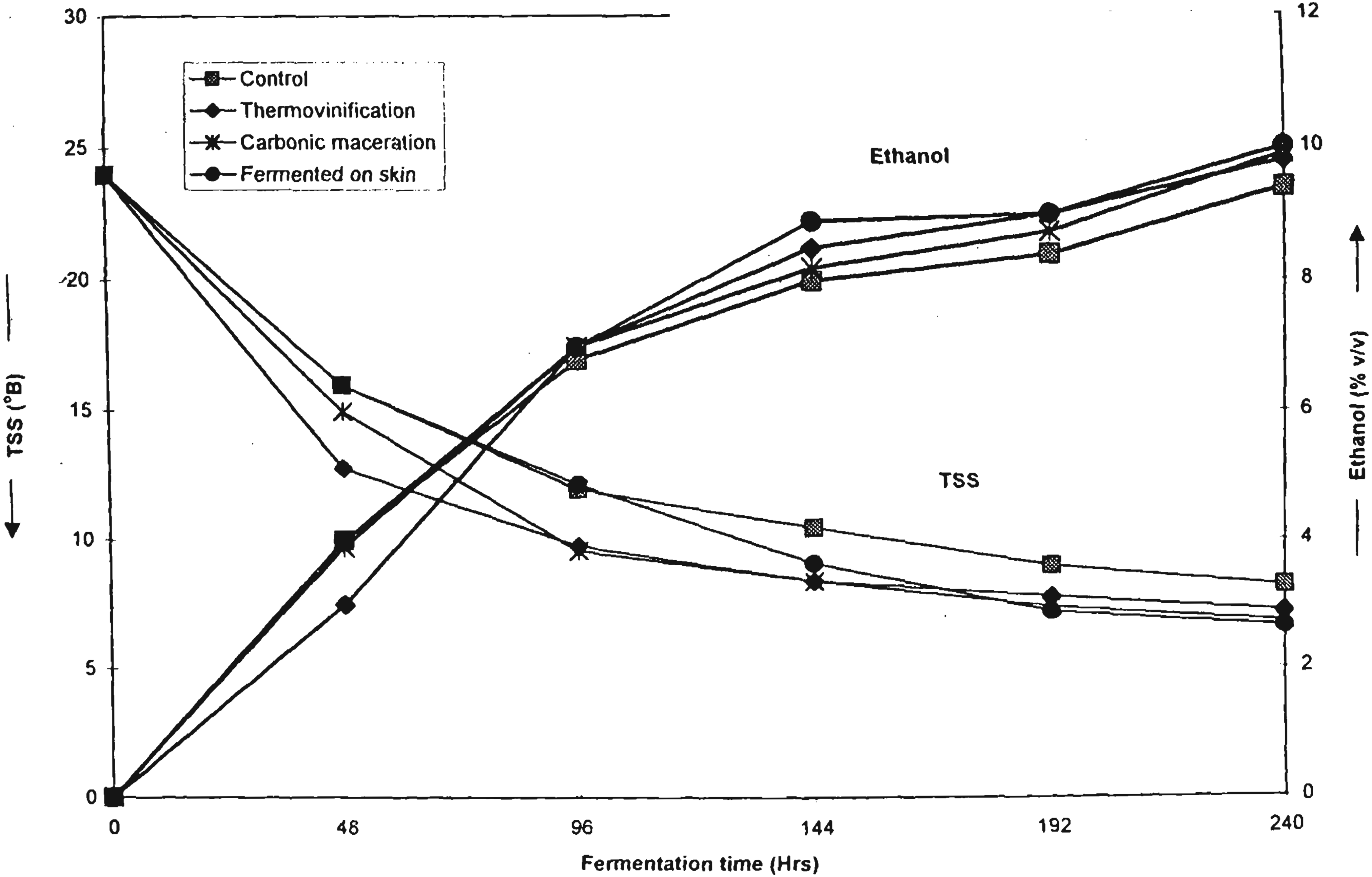


Fig. 4.2.4. Comparison of fermentation behaviour and ethanol production of different strawberry musts of different treatments

Table 4.2.1. Effect of varieties and treatments on total soluble solids (°B), total sugar (%) and reducing sugar (%) of different strawberry wines

Varieties	Treatments				
	Control (T_1)	Thermovinification (T_2)	Carbonic maceration (T_3)	Fermented on the skin (T_4)	Mean
TSS(°B)					
Camarosa	10.6	10.4	9.8	7.8	9.7
Chandler	8.3	7.6	8.3	8.3	8.1
Doughlas	10.1	8.0	9.1	8.1	8.8
Mean	9.6	8.6	9.1	8.1	
CD(P≥0.05) Treatments : 0.053, Cultivars : 0.053, Treatment x Cultivar : 0.046					
Total sugars(%)					
Camarosa	2.0	1.8	1.6	1.1	1.7
Chandler	0.7	0.5	0.7	0.7	0.6
Doughlas	1.6	0.7	1.1	0.5	1.0
Mean	1.4	1.0	1.2	0.8	
CD(P≥0.05) Treatments : 0.046, Cultivars : 0.039, Treatment x Cultivar : 0.055					
Reducing sugars(%)					
Camarosa	0.139	0.139	0.130	0.134	0.135
Chandler	0.124	0.117	0.129	0.125	0.124
Doughlas	0.131	0.122	0.131	0.127	0.128
Mean	0.131	0.126	0.130	0.129	
CD(P≥0.05) Treatments : NS, Cultivars : 0.003, Treatment x Cultivar : 0.004					

wines of different cultivars and methods ranged between 8.0 and 9.6°B for TSS. The highest TSS was observed in Camarosa (9.6°B) and lowest (8.0°B) in Chandler. Amongst the treatments, it was observed that the highest TSS (9.6°B) was in control and the lowest (8.1°B) in must fermented on the skin which is in accordance with their rates of fermentation (RF) described earlier. The interaction of treatment with cultivar was significant. Control wine from Camarosa cultivar had the highest TSS (10.6) followed by Camarosa thermovinified wine (10.4) and the lowest (7.6) in Chandler thermovinified wines. It is on the expected lines that the must having the highest rate of fermentation had lowest total soluble solids and vice-versa.

The results (Table 4.2.1) show that there were significant differences among the wines for total and reducing sugars. But in absolute terms, the differences were not appreciable. Total sugars in different wines ranged between 0.62 to 1.7 per cent. The highest total sugars however, were recorded (1.7%) in Camarosa and lowest (0.62%) in Chandler. Among the treatments, control had the highest (1.42%) and that fermented on the skin lowest (0.79%) reducing sugars. Among the interactions, Camarosa control wine had the highest total sugars (2.0%) and Chandler thermovinified wines the lowest (0.5%). Wine from Doughlas cultivar fermented on the skin was found at par with Chandler thermovinified wine.

The data (Table 4.2.1) further revealed that there were also significant differences for reducing sugars among the different cultivar wines. But for various treatments, the differences for reducing sugars were non-significant. All the wines of the treatments were at par with thermovinified wines. In different wines, reducing sugars were found in the range of 0.124 to 0.135 per cent. The highest reducing sugar was recorded (0.135%) in Camarosa and the lowest (0.124%) in Chandler. Among the methods, the highest (0.131%) was observed in control wines and the lowest (0.126%) in thermovinified wines. It was further evidenced from the data that the highest reducing sugars (0.139%) in control wine from Camarosa and the lowest (0.177%) was found in Chandler thermovinified wines. Based upon both the total and reducing sugar content, all the strawberry wines could be called as "dry wines".

Titratable acidity, pH and colour

Table 4.2.2 summarizes the titratable acidity, pH and colour of different wines. It is discernible from the data that titratable acidity of wine made from Chandler cultivar was significantly different from the other two cultivars. However, Camarosa and Doughlas were at par with each other. Further, it is revealed that wines of different methods were significantly different from each other. The titratable acidity of different wines ranged between 0.65 to 0.73 per cent. The highest acidity was recorded (0.73%) in Chandler and the lowest (0.65%) in Camarosa and Doughlas. Among the methods, carbonic macerated wines recorded the lowest acidity (0.63%) and thermovinified (0.73%) highest. Wines fermented on the skin were found at par with control wines. Among the interaction of treatment and cultivar, the highest titratable acidity was found (0.76%) in thermovinified wines from Doughlas cultivar which was at par with carbonic macerated wine of cultivar Chandler. The lowest titratable acidity (0.58%) was recorded in carbonic macerated wine from Camarosa which was at par with control wine from Doughlas cultivar. Carroll (1986) has also reported that carbonic macerated wines have the lower acidity, higher pH in comparison with standard red wines i.e. fermented on the skin and normally fermenting juice because there is degradation of malic acid as a result of malolactic fermentation in carbonic macerated wines.

Perusal of the Table 4.2.2 further revealed that the pH of different wines was significantly different from each other. The pH ranged between 3.18 to 3.26. Wines of different cultivars and treatments differed significantly. The highest pH (3.26) was recorded in Doughlas and lowest (3.18) in Camarosa. Among the treatments, carbonic macerated wines had the highest (3.24) pH while the lowest pH (3.19) was that of the control wine. Among the interactions, the highest pH recorded was (3.33) in thermovinified wine from Doughlas cultivar and lowest (3.13) in carbonic macerated wine from Camarosa cultivar. Carroll (1986) found that the carbonic macerated wines have higher pH, lower acidity due to anaerobic conditions of fermentation. Amerine and Ough (1968) reported that holding whole grapes

Table 4.2.2. Effect of varieties and treatments on titratable acidity, pH and colour of different strawberry wines

Varieties	Treatments				
	Control (T_1)	Thermovinification (T_2)	Carbonic maceration (T_3)	Fermented on the skin (T_4)	Mean
Titratable acidity					
Camarosa	0.68	0.69	0.58	0.66	0.65
Chandler	0.73	0.74	0.71	0.72	0.73
Doughlas	0.59	0.76	0.61	0.62	0.65
Mean	0.67	0.73	0.63	0.67	
CD(P≥0.05) Treatments : 0.035, Cultivars : 0.030, Treatment x Cultivar : 0.041					
pH					
Camarosa	3.14	3.15	3.13	3.32	3.18
Chandler	3.15	3.20	3.31	3.19	3.21
Doughlas	3.29	3.33	3.30	3.15	3.26
Mean	3.19	3.23	3.24	3.22	
CD(P≥0.05) Treatments : 0.018, Cultivars : 0.016, Treatment x Cultivar : 0.041					

Colour

	Red	Yellow	Red	Yellow	Red	Yellow	Red	Yellow	Red	Yellow
Camarosa	16.00	19.50	17.25	15.00	13.25	16.50	11.00	18.58	14.38	17.40
Chandler	12.50	17.75	13.67	17.00	8.58	20.08	8.10	22.50	10.72	19.33
Doughlas	6.58	12.62	8.0	13.75	7.96	18.50	15.25	14.50	9.45	14.84
Mean	11.69	16.62	12.97	15.25	9.93	18.36	11.45	18.53		

CD(P≥0.05) Treatments : R1.11, Y0.89, Cultivars : R=0.96, Y=0.769, Treatment x Cultivar : R=1.365, Y=1.071

anaerobically will cause cellular death and acids such as malic which may decrease in concentration.

It is also discernible from the data that variation in colour units of different wines was quite evident. There were significant differences among different wines. The red colour units ranged between 9.45 to 15.0. The highest red colour units were observed in Camarosa (14.38) and lowest (9.45) in Doughlas. The yellow colour units varied from 15 to 19 units. The highest yellow colour units were observed in Chandler (19.33) and lowest (14.84) in Doughlas. Among different methods of wine preparation, the highest red colour units (12.97) were recorded in thermovinified wines and lowest (9.93) in carbonic macerated wines. The highest yellow colour units were observed (18.53) in wine fermented on the skin and the lowest (15.25) in thermovinified wines. It was further evidenced from the data (Table 4.2.2) that highest red colour units (17.25) were in thermovinified wine from Camarosa cultivar and lowest (7.96) in carbonic macerated wines from Doughlas cultivar. The temperature employed, time and the skin juice contact during thermovinification, are reported to control the extent of extraction. Such juices are generally intensely coloured (Boulton *et al.*, 1996)

Alcohol, higher alcohols and volatile acidity

Table 4.2.3 summarizes the result of alcohol, higher alcohol and volatile acidity in different wines. The data on the alcohol content in different wines revealed that wines of different cultivars differ significantly. Among the treatments, control and carbonic macerated wines were at par with each other and significantly different from thermovinified wines. Thermovinified and that fermented on the skin wines were at par with each other. The alcohol in different wines was recorded in the range between 9.2 to 11.5 per cent. The highest alcohol was recorded (11.5%) in Chandler and lowest (9.2%) in Camarosa. Among the treatments, carbonic macerated wines has the highest alcohol content (10.8%) and the lowest (10.3%) in thermovinified wines. Among the interaction of treatment and cultivar, the highest ethanol content was found (12.5%) in carbonic macerated Chandler cultivar wine

Table 4.2.3. Effect of varieties and treatments on ethanol (% v/v), higher alcohols (mg/l) and volatile acidity (% A/A) of different strawberry wines

Varieties	Treatments				
	Control (T_1)	Thermovinification (T_2)	Carbonic maceration (T_3)	Fermented on the skin (T_4)	Mean
Ethanol (% v/v)					
Camarosa	11.3	11.7	10.9	10.8	11.2
Chandler	11.2	10.0	12.5	12.3	11.5
Doughlas	9.8	9.3	9.0	8.9	9.2
Mean	10.8	10.3	10.8	10.6	
CD(P≥0.05) Treatments : 0.423, Cultivars : 0.366, Treatment x Cultivar : 0.51					
Higher alcohol (mg/l)					
Camarosa	158	154	154	154	155
Chandler	170	172	165	168	169
Doughlas	157	152	145	148	151
Mean	162	159	154	157	
CD(P≥0.05) Treatments : 0.720, Cultivars : 0.672, Treatment x Cultivar : 0.885					
Volatile acidity (% A/A)					
Camarosa	0.026	0.029	0.025	0.026	0.026
Chandler	0.040	0.030	0.030	0.030	0.032
Doughlas	0.021	0.030	0.025	0.024	0.025
Mean	0.029	0.030	0.027	0.027	
CD(P≥0.05) Treatments : 0.001, Cultivars : 0.0006, Treatment x Cultivar : 0.001					

which was at par with that fermented on the skin wine from Chandler cultivar. The lowest (8.9%) ethanol content was found in fermented on the skin wine from Doughlas cultivar which was at par with that thermovinified and fermented on the skin wine from Doughlas cultivar. The alcohol content of wines of different cultivars and treatments correlated with their respective rates of fermentation as described earlier. The results are further in confirmation with the earlier reports of Amerine *et al.* (1980). The range of alcohol content reported in fruit wines was 10.6 to 11.7 per cent (Joshi *et al.*, 1999) and in grape wine 9.7 to 12.8 per cent (Kundu *et al.*, 1976). Based upon the absolute values of ethanol, wines from all the cultivars could be classified as (red) table wines. Although the TSS (°B) of all the musts was kept 24°B, the ethanol differed significantly among the wines from different cultivars and methods which could be attributed to the differences in composition of other nutrient in respective musts (Kulkarni *et al.*, 1980) and conditions during fermentation (Carroll, 1986). As carbonic macerated wines have been made under anaerobic conditions so yielded more alcohol as observed by Carroll (1986). Although earlier Amerine and Ough (1968) reported less fermentation during carbonic maceration.

The amount of higher alcohols in different wines (Table 4.2.3) were significantly different among wines of different cultivars and treatments. Higher alcohols are reported to range between 151 to 169 mg/l. The highest higher alcohols content was observed (169 mg/l) in Chandler and lowest (151 mg/l) in Doughlas cultivar wine, respectively. Among the different treatments, the highest quantity of higher alcohols (162 mg/l) was observed in control and the lowest (154 mg/l) in carbonic maceration. Among the interaction of treatment and cultivar, the highest higher alcohols (172 mg/l) was found in thermovinified wine from Chandler cultivar and lowest (145 mg/l) in carbonic macerated wine from Doughlas cultivar. Control wine from Chandler was found at par with thermovinified wine from Chandler cultivar. However, the values reported for grape wine and peach wine ranged from 140 to 420 mg/l and 113 to 154.3 mg/l. The results fall within the reported range of higher alcohols. At low concentration, the higher alcohols may play an important role in sensory quality (Amerine *et al.*, 1980) though at higher concentration these impart undesirable properties to the wines (Fowles, 1989). Lesser quantity of higher alcohols denotes the non-oxidative conditions of all the wines (Guymon *et al.*, 1961) and which indirectly reflects the proper conditions of wine preparation adopted in this study.

Table 4.2.3 summarizes the volatile acidity of different wines. The volatile acidity of wines of different cultivars differed significantly. However, amongst the treatments, control and thermovinified wines were significantly different from carbonic macerated wines and those fermented on the skin. Carbonic macerated wines were at par with those fermented on the skin wines. The volatile acidity of different wines ranged between 0.025 to 0.032 per cent acetic acid. The highest volatile acidity was recorded (0.032% A.A.) in Chandler and lowest (0.025% A.A) in Doughlas. Among the treatments, carbonic macerated wines and those fermented on the skin have lowest (0.027% A.A) volatile acidity while the highest (0.030% A.A) volatile acidity was recorded in thermovinified wines. It was further evidenced from the data (Table 4.2.3) that highest volatile acidity was found (0.040% A.A) in control wine from Chandler cultivar and the lowest (0.021%) in control wine from Doughlas cultivar. Whereas thermovinified wine from Chandler and Doughlas were at par with carbonic macerated and fermented on the skin wines from Chandler cultivar with 0.030% (A.A) volatile acidity. The volatile acidity content of more than 0.04% acetic acid indicated acetification of wine (Amerine *et al.*, 1980). Hence, from the volatile acidity point of view the wines from all the cultivars can be considered to be sound which indirectly showed proper methodology applied in preparation of wine.

Esters; phenols and anthocyanins

The data presented (Table 4.2.4) on the ester content of different wines revealed that total ester content of different wines was significantly different from each other. The esters ranged between 78.3 to 102.4 mg/l. The highest ester content (102.4 mg/l) was found in Doughlas and the lowest (78.3 mg/l) in Chandler.

Table 4.2.4. Effect of varieties and treatments on esters (mg/L), phenols (mg/l) and anthocyanins (OD/ml of wine) content of different strawberry wines

Varieties	Treatments				
	Control (T_1)	Thermovinification (T_2)	Carbonic maceration (T_3)	Fermented on the skin (T_4)	Mean
Esters (mg/l)					
Camarosa	86.0	94.0	102.0	81.3	90.9
Chandler	74.6	79.2	84.3	75.1	78.3
Doughlas	100.1	103.1	110.7	96.0	102.4
Mean	86.9	92.1	99.0	84.1	
CD($P \geq 0.05$) Treatments : 0.780, Cultivars : 0.675, Treatment x Cultivar : 0.954					
Phenols (mg/l)					
Camarosa	139.7	150.2	138.7	150.3	144.7
Chandler	117.0	137.5	131.5	133.2	129.8
Doughlas	123.7	146.0	128.2	143.2	135.2
Mean	126.8	144.5	132.8	142.2	
CD($P \geq 0.05$) Treatments : 3.94, Cultivars : 3.41, Treatment x Cultivar : 4.82					
Anthocyanins (OD/ml of wine)					
Camarosa	0.188	0.132	0.135	0.145	0.150
Chandler	0.158	0.137	0.144	0.144	0.145
Doughlas	0.111	0.097	0.108	0.108	0.104
Mean	0.152	0.122	0.127	0.132	
CD($P \geq 0.05$) Treatments : 0.025, Cultivars : 0.022, Treatment x Cultivar : 0.031					

Amongst the different treatments ester content also differed significantly. The highest ester content (99.0 mg/l) was recorded in carbonic macerated wines and the lowest (84.1 mg/l) in fermented on the skin. Among the interactions of treatment and cultivars, the highest esters (110.7 mg/l) were recorded in carbonic macerated wines from Doughlas cultivar and the lowest (81.3 mg/l) in fermented on the skin wine from Camarosa cultivar. Total esters of wines determine the fruity aroma and their amount has been linked with the type of fruit, fermentation conditions (Amerine *et al.*, 1980; Joshi, 1997). Boulton *et al.* (1996) also reported that during carbonic maceration, the cell walls in the skin become permeable allowing the pigments and esters to leak into the intracellular fluid which might be the reason for higher ester content in the wines from carbonic maceration. Doughlas cultivar was the best with regards to the ester content.

The phenol content of different wines (Table 4.2.4) revealed that there was significant difference among the wines of different cultivars and treatments. The phenols in different wines ranged between 129.8 to 144.6 mg/l. The highest phenols were recorded (144.6 mg/l) in Camarosa and the lowest (129.8 mg/l) in Chandler. Among the treatments, highest phenols were (144.6 mg/l) in thermovinified wines and lowest (126.8 mg/l) in control wines. It was further evidenced from the data that the highest quantity of phenols (150.3 mg/l) was found in fermented on the skin wine from Camarosa cultivar and the lowest (117.0 mg/l) in control wine from Chandler cultivar. Thermovinified wine from Chandler and Doughlas cultivars were found at par with fermented on the skin wine from Camarosa cultivar.

Perusal of Table (4.2.4) revealed that there were significant differences in anthocyanins among the cultivars and treatments. The anthocyanin (optical density/ml of wine) ranged between 0.106 to 0.150 in various cultivar wines. The highest optical density was observed (0.150) in Camarosa and the lowest (0.104) in Doughlas. Among the treatments, the highest (0.152) was observed in control and the lowest (0.122) in thermovinified wines. Among the interactions of treatment and cultivars, the highest anthocyanins were recorded (0.188) in control wine from

Camarosa cultivar and lowest (0.097) in thermovinified wine from Doughlas cultivar. Control, thermovinified, carbonic macerated wines from Chandler cultivar were found at par with control wine from Camarosa cultivar. However, carbonic macerated and those fermented on the skin wines from Doughlas cultivar were found at par with thermovinified wines for this parameter. Our results are in conformity with those given by Timberlake and Bridle (1976) reporting that although the colour of thermovinified wines was more than that fermented on the skin and carbonic maceration yet had lower anthocyanin than the other two methods and this might be due to higher pH.

An overview of the results, presented in various sections show that application of various treatments have certainly improved the fermentation behaviour of strawberry musts. This is further corroborated with physico-chemical characteristics of control wine having higher TSS, total sugars, reducing sugars and more quantity of higher alcohols. Very important characteristics like total phenols, esters and colour with comparable amount of higher alcohols, volatile acidity, ethyl alcohol, sugars and anthocyanin were found in thermovinified wines which are quite desirable for production of quality wines. The carbonic macerated wines were typical having larger amount of alcohol, higher pH, lower acidity, lesser higher alcohol and volatile acidity. The variation in these parameters is associated with the mode of fermentation conducted in carbonic maceration. Fermented on the skin was typical for higher amount of anthocyanin, lower reducing sugar, total sugar then control wines. This is quite apparent as the fermentation was conducted on the skin thereby, more constituent like colour, phenols, were extracted more than the normal fermentation conducted without skin as is found in grape wine (Timberlake and Bridle, 1976; Carroll, 1986; Lorincz, 1998).

From the quality point of view, higher amount of ethyl alcohol, low acidity, lesser amount of higher alcohols and volatile acidity constitute the desirable characteristics and such findings on grape fermentation have already been made (Amerine *et al.*, 1980; Carroll, 1986). From the ongoing discussion, it is clear that the wine made by thermovinification has many desirable quality characteristics over the control as well as other treatments tried for preparation of quality wine, but where reduction in acidity is considered more important, carbonic maceration method seems to have an edge over others for production of quality strawberry wine.

Amongst the cultivar, wines from Camarosa cultivar had many desirable characteristics like more esters, better amount of acidity, red colour units and other comparable characteristics alcohol and phenols, while the wine from Chandler cultivar had higher amount of ethyl alcohol, more phenols, anthocyanin than other cultivars. Some of these differences are correlated with their initial characteristics, others have been influenced by method of vinification. On these basis, Camarosa cultivar seems to have edge over others. But the final decision about the best method and cultivar need the input of sensory quality which is being discussed in later section.

4.3 DETERMINE CHANGES OCCURRING IN WINES DURING MATURATION

Changes during maturation

Total soluble solids (°B)

Results (Table 4.3.1) show that during maturation change in TSS was significant, but in absolute terms the decrease in TSS was not appreciable. There is a decrease in TSS(°B) of all the cultivar wines as well as treatments during storage. However, both the treatments and cultivars maintained their initial differences even after maturation. Interaction between the cultivars, treatments and maturation were found significant. Among the cultivars, wines from Chandler cultivar was found at par during 6 and 9 months interval, whereas among treatments (Fig. 4.3.1) wines fermented on the skin were found at par at 6 and 9 months interval. Precipitation of soluble solids during interaction of various components might have resulted in decrease of TSS during maturation (Joshi *et al.*, 1999).

Table 4.3.1 Changes in total soluble solids (°B) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	10.8	10.6	10.5	10.5	10.6	8.4	8.2	8.2	8.2	8.3	10.4	10.2	10.0	9.8	10.1	9.6
Thermovinification	10.6	10.4	10.2	10.2	10.4	7.8	7.6	7.4	7.3	7.5	8.2	8.0	7.8	7.8	8.0	8.6
Carbonic maceration	10.1	9.8	9.8	9.7	9.8	8.4	8.4	8.2	8.2	8.3	9.4	9.2	9.0	8.8	9.1	9.1
Fermented on the skin	8.0	7.8	7.8	7.8	7.8	8.4	8.4	8.2	8.2	8.3	8.4	8.2	8.0	8.0	8.1	8.1
Mean (VxM)	9.8	9.7	9.6	9.6		8.3	8.2	8.0	8.0		9.1	8.9	8.7	8.6		
Storage means (M)	9.0	8.9	8.7	8.7												
Cultivar means (V)	9.6	8.1	8.8													

CD ($P \geq 0.05$) Treatments(T) : 0.053, Cultivars(V) : 0.046, Storage(M) : 0.053
TxV : 0.065, VxM : 0.063, TxVxM : 0.129

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Total sugars

Table 4.3.2 show that during first 3 months, there is a significant decrease in total sugars but after that the values for total sugars were at par. The data further revealed that there was significant difference among the cultivars and decrease in total sugars was recorded. The lowest total sugar (0.62%) was observed in Chandler and highest (1.70) in Camarosa. Similarly, decrease in total sugars was also observed among the different wine treatments (Fig. 4.3.1). Among the interactions of cultivars and storage, wines from Camarosa cultivar was found at par at 0 and 3 month interval. However, among the treatments significant difference among the interactions was observed. So, the decrease in total sugar might be due to the activity of polyphenol oxidase which catalyzed enzymatic browning or by Maillard's reaction resulting non-enzymatic browning due to reaction of sugar with amino acids (Zoeckleing etal 1995). The decrease in total sugar is not desirable as it increases the browning in wine, thus affecting the colour appeal of wine.

Reducing sugars

Table 4.3.3 shows that there was a significant increase in reducing sugars in different wines during maturation. The increase in reducing sugars of wines of different cultivars and treatments was also observed during maturation of wine (Fig. 4.3.1). Among the interactions of cultivars, treatments and storage, there were significant differences during maturation. However, the differences in reducing sugar present initially between different cultivars and the treatments were also observed after maturation. The increasing trend of reducing sugar is apparently the result of hydrolysis of total sugars into reducing sugars during maturation (Amerine *et al.*, 1980). It is significant from taste, quality of wine and is one of the desirable effects of maturation of wine.

Table 4.3.2 Changes in total sugars (%) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	2.3	2.2	2.1	1.8	2.1	0.70	0.68	0.52	0.32	0.55	1.8	1.7	1.6	1.5	1.6	1.4
Thermovinification	2.2	2.0	1.6	1.6	1.8	0.59	0.59	0.35	0.32	0.46	0.90	0.74	0.61	0.60	0.71	1.0
Carbonic maceration	1.9	1.7	1.6	1.4	1.6	0.83	0.83	0.73	0.70	0.77	1.5	1.1	1.0	0.98	1.1	1.2
Fermented on the skin	1.3	1.3	1.2	0.99	1.2	0.79	0.78	0.62	0.62	0.70	0.62	0.51	0.40	0.39	0.48	0.80
Mean (VxM)	1.9	1.8	1.6	1.4		0.73	0.72	0.56	0.49		1.2	1.0	0.90	0.86		
Storage means (M)	1.3	1.2	1.0	1.0												
Cultivars means (V)	1.7	0.62	1.0													

CD ($P \geq 0.05$) Treatments(T) : 0.046, Cultivars(V) : 0.039, Storage(M) : 0.046
TxV : 0.055, VxM : 0.055, TxVxM : 0.110

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Table 4.3.3 Changes in reducing sugars (%) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	0.100	0.138	0.157	0.163	0.139	0.072	0.120	0.149	0.156	0.124	0.080	0.124	0.153	0.168	0.131	0.131
Thermovinification	0.087	0.130	0.167	0.173	0.139	0.064	0.116	0.142	0.149	0.117	0.079	0.118	0.138	0.153	0.122	0.126
Carbonic maceration	0.085	0.128	0.148	0.161	0.130	0.079	0.129	0.151	0.157	0.129	0.082	0.125	0.157	0.162	0.131	0.130
Fermented on the skin	0.082	0.132	0.151	0.171	0.134	0.075	0.126	0.149	0.152	0.125	0.084	0.130	0.142	0.153	0.127	0.129
Mean (VxM)	0.088	0.132	0.155	0.167		0.072	0.122	0.147	0.153		0.081	0.124	0.147	0.159		
Storage means (M)	0.080	0.126	0.149	0.159												
Cultivar means (V)	0.135	0.124	0.128													

CD ($P \geq 0.05$) Treatments(T) : NS, Cultivars(V) : 0.003, Storage(M) : 0.040
TxV : 0.004, VxM : 0.004, TxVxM : 0.008

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

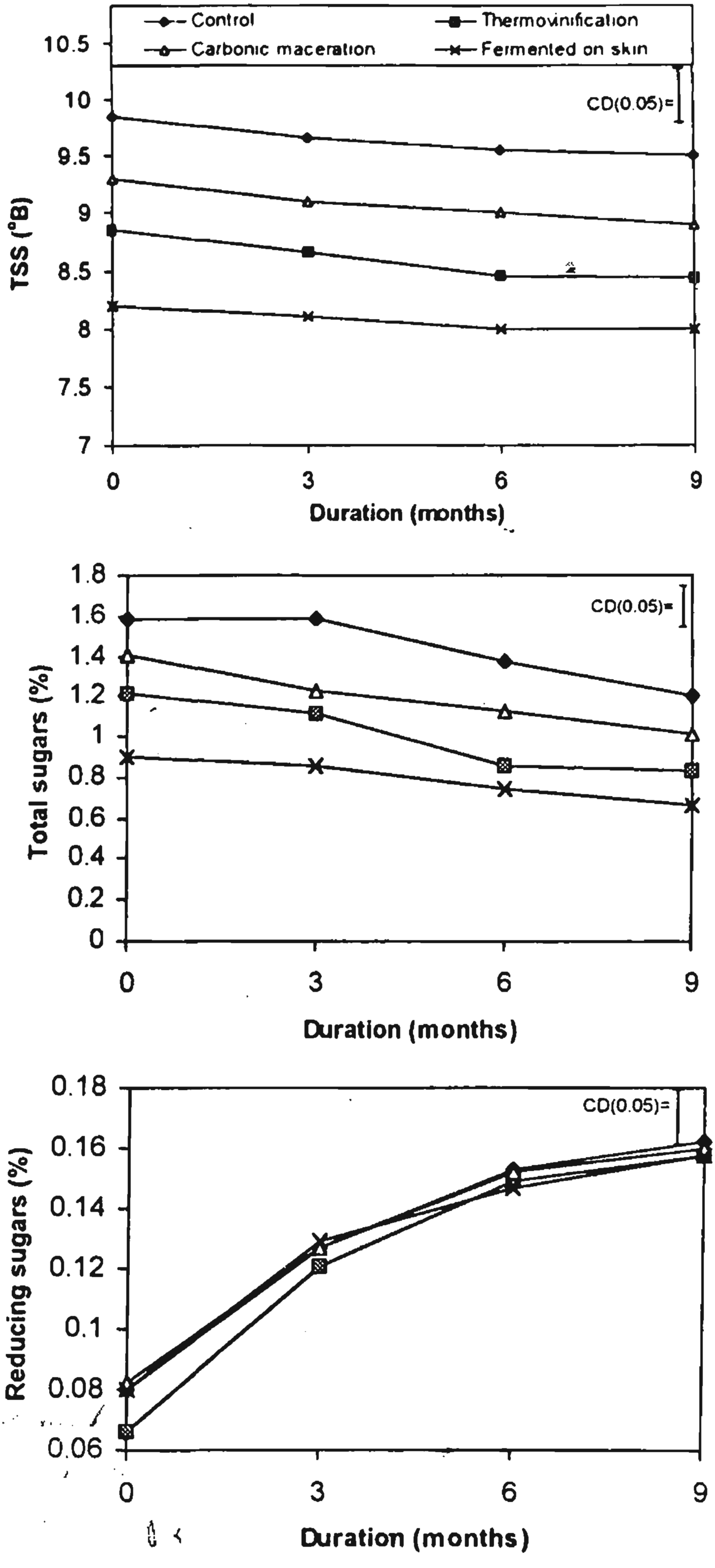


Fig. 4.3.1. Changes in total soluble solids (°B), total sugars and reducing sugars (%) during maturation of different treatments strawberry wine

Titratable acidity

It is also discernible from the data (Table 4.3.4) that during maturation, changes in titratable acidity were significant. Further, there was a decrease in titratable acidity of wines of different cultivars during maturation. Chandler recorded the highest while Doughlas and Camarosa had the lowest. However, the latter two cultivars were at par with each other. The similar trend was noticed after maturation. Among the treatments also, there was a reduction in titratable acidity with advancement of maturation. Among the interactions, during storage Chandler cultivar was found at par whereas wines from Doughlas and Camarosa cultivar were found at par at 6 and 9 months interval. However, among the treatments interaction (Fig. 4.3.2), thermovinified wines were found at par during storage of 9 months, whereas wines made by carbonic maceration were found at par during 6 and 9 months interval. The highest acidity before and after maturation was recorded in thermovinified wines. The decrease in acidity in wines during maturation absolute terms was not appreciable. The possible reason for the decrease in acidity would be the precipitation of different acids in the form of their respective salts (Amerine *et al.*, 1980). The decrease in titratable acidity is desirable in wines from acidic fruits during maturation as it increases the palatability of wine (Joshi *et al.*, 1999).

pH

During maturation, the changes in titratable acidity discussed earlier of different wines are confirmed by changes in pH shown in Table 4.3.5. There was a significant increase in pH of different wines. Further, there was an increase in pH with maturation in all the wines of all the cultivars and treatments. Among the interactions plotted in Fig. 4.3.2, there were significant differences during maturation between wines of different treatments and cultivars. However, wines from Doughlas cultivar were found at par after 3 months of maturation. Whereas among the treatments, wines made by normal fermentation and fermented on the skin were found initially at par. But thermovinified wines were found at par with carbonic macerated wines during 6 and 9 months of storage. However, the wines maintained

Table 4.3.4 Changes in titratable acidity (%) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Douglas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	0.72	0.70	0.66	0.65	0.68	0.76	0.74	0.72	0.71	0.73	0.64	0.60	0.58	0.56	0.59	0.67
Thermovinification	0.73	0.71	0.67	0.67	0.69	0.76	0.75	0.74	0.74	0.74	0.79	0.78	0.76	0.74	0.76	0.73
Carbonic maceration	0.63	0.60	0.56	0.55	0.58	0.73	0.72	0.71	0.70	0.71	0.62	0.70	0.58	0.57	0.61	0.63
Fermented on the skin	0.70	0.66	0.65	0.64	0.66	0.74	0.74	0.72	0.71	0.72	0.65	0.63	0.62	0.61	0.62	0.67
Mean (VxM)	0.69	0.66	0.63	0.62		0.74	0.73	0.72	0.71		0.67	0.67	0.63	0.62		
Storage means (M)	0.70	0.69	0.66	0.65												
Cultivar means (V)	0.65	0.73	0.65													

CD ($P \geq 0.05$) Treatments(T) : 0.035, Cultivars(V) : 0.030, Storage(M) : 0.035
TxV : 0.041, VxM : 0.041, TxVxM : 0.085

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Table 4.3.5 Changes in pH during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	3.12	3.13	3.15	3.17	3.14	3.12	3.14	3.16	3.18	3.15	3.26	3.28	3.30	3.32	3.29	3.19
Thermovinification	3.10	3.14	3.18	3.19	3.15	3.20	3.18	3.21	3.23	3.20	3.28	3.32	3.36	3.38	3.33	3.23
Carbonic maceration	3.12	3.12	3.13	3.15	3.13	3.32	3.25	3.34	3.36	3.31	3.28	3.30	3.30	3.32	3.30	3.24
Fermented on the skin	3.18	3.35	3.37	3.39	3.32	3.15	3.18	3.21	3.23	3.19	2.90	3.10	3.20	3.40	3.15	3.22
Mean (VxM)	3.13	3.18	3.20	3.22		3.19	3.18	3.23	3.25		3.18	3.25	3.29	3.35		
Storage means (M)	3.16	3.20	3.24	3.27												
Cultivar means (V)	3.18	3.21	3.26													

CD ($P \geq 0.05$) Treatments(T) : 0.018, Cultivars(V) : 0.016, Storage(M) : 0.019
TxV : 0.023, VxM : 0.023, TxVxM : 0.045

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

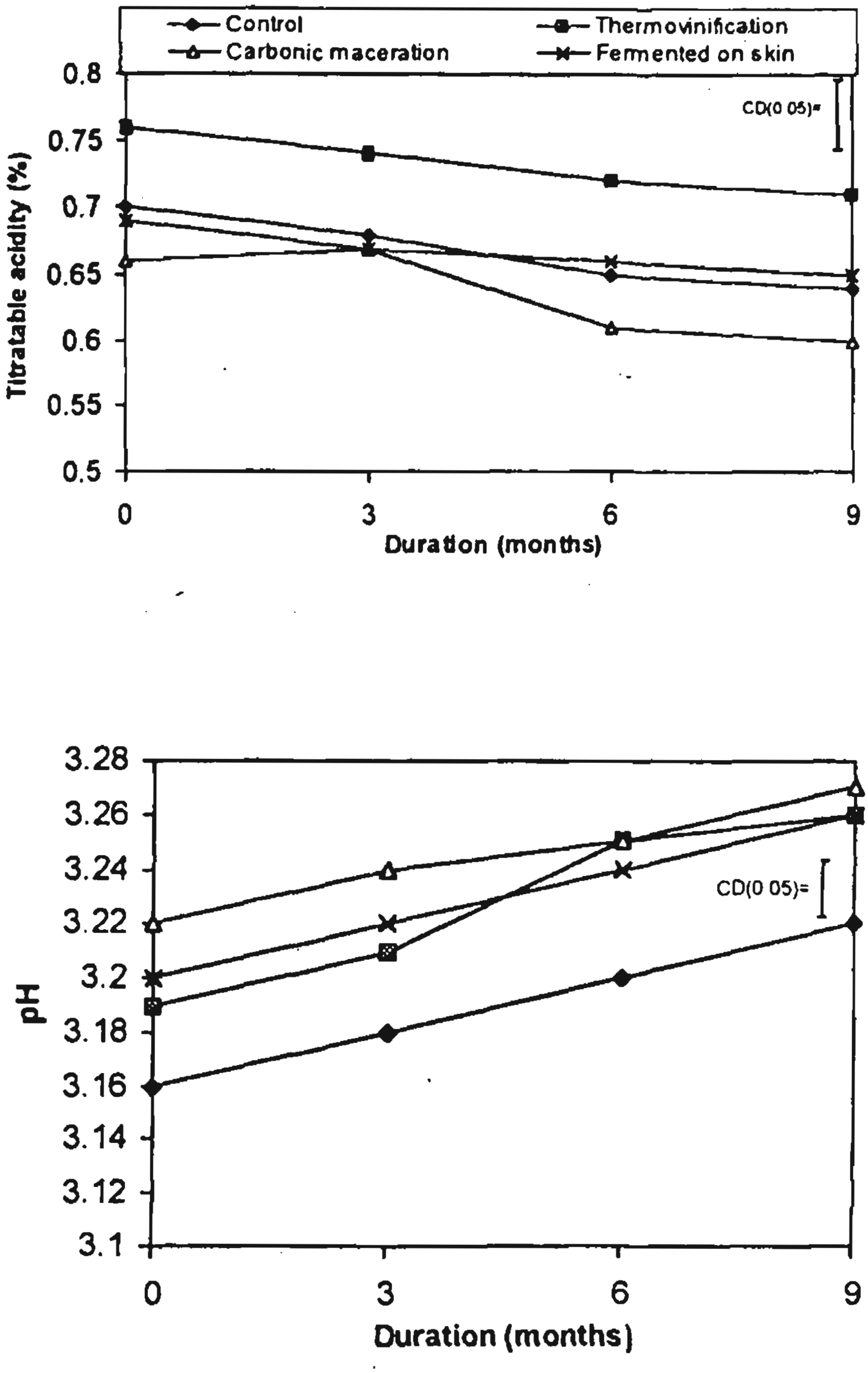


Fig. 4.3.2. Changes in titratable acidity and pH during maturation of different treatments strawberry wine

their initial differences during and after maturation. In absolute terms, whatever changes took place could be correlated with the precipitation of acids as salts discussed earlier.

Alcohol

Table 4.3.6 shows that ethanol content of the wines was non-significantly decreased during storage. The highest ethanol was recorded in Chandler initially and after maturation maintained the same trend. A slight decrease in ethanol in Doughlas cultivar wine was also recorded. However, no particular trend was observed in other two cultivars. Among the treatments, there was a non-significant increase in ethanol during maturation. Irrespective of treatment or cultivar, the alcohol content remained almost the same. Among the interactions also, there was no significant difference. However, the trend is shown in Fig. 4.3.3. The slight decrease in absolute terms might be due to the reaction of alcohol with acids to form esters (Amerine *et al.*, 1980; Zoecklein *et al.*, 1995).

Higher alcohols

Results in Table 4.3.7 show that during maturation changes in higher alcohols were found to be significant. There was a decrease in fusel alcohol content of wine during maturation. Among the cultivars, the highest fusel alcohol was found in Chandler initially and remained on the similar lines even after maturation. In treatment also, the trend remains the same i.e. highest in control and lowest in wine from the must fermented on the skin. Among the interactions of treatments (Fig. 4.3.3), cultivars and storage, there were significant differences during maturation. However, wines from cultivar Doughlas were at par during 6 and 9 months interval. A decrease was recorded in fusel alcohol content of different cultivar and treatment wines. The amount of higher alcohols in table wines varied from about 140 to 420 mg/l and in dessert wines from about 160 to 900 mg/l (Amerine *et al.*, 1980). Guymon and Heitz (1952) and Villforth and Schmidt (1953) showed that red wines contain slightly more higher alcohols than white. Since in these wines higher alcohols are in the range described above it indicates that proper storage conditions

Table 4.3.6 Changes in ethanol (% v/v) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	11.3	11.3	11.3	11.4	11.3	11.1	11.1	11.1	11.1	11.1	9.8	9.8	9.8	9.8	9.8	10.8
Thermovinification	11.7	11.7	11.7	11.7	11.7	9.8	10.0	10.0	10.0	10.0	9.2	9.2	9.2	9.2	9.2	10.3
Carbonic maceration	10.8	10.8	10.8	10.8	10.8	12.4	12.6	12.5	12.6	12.5	8.9	8.9	9.0	9.0	8.9	10.8
Fermented on the skin	10.7	10.7	10.7	10.7	10.7	12.2	12.3	12.3	12.3	12.3	9.0	9.0	9.0	9.0	9.0	10.6
Mean (VxM)	11.1	11.1	11.1	11.1		11.4	11.5	11.5	11.5		9.3	9.2	9.2	9.2		
Storage means (M)	10.6	10.6	10.6	10.6												
Cultivar means (V)	11.2	11.5	9.2													

CD ($P \geq 0.05$) Treatments(T) : 0.423, Cultivars(V) : 0.366, Storage(M) : NS
TxV : 0.51, VxM : NS, TxVxM : NS

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Table 4.3.7 Changes in higher alcohol (mg/l) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	169	158	153	152	158	180	175	169	157	170	167	159	152	150	157	162
Thermovinification	162	151	151	150	154	187	178	165	159	172	159	151	148	151	152	159
Carbonic maceration	159	154	152	149	154	182	169	157	152	165	149	142	144	144	145	154
Fermented on the skin	163	158	149	147	154	178	168	163	161	168	152	148	145	147	148	157
Mean (VxM)	163	155	151	149		182	173	164	157		157	150	147	148		
Storage means (M)	167	159	154	152												
Cultivar means (V)	155	169	151													

CD ($P \geq 0.05$) Treatments(T) : 0.720, Cultivars(V) : 0.627, Storage(M) : 0.724
TxV : 0.875, VxM : 0.885, TxVxM : 1.77

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

during maturation of wine i.e. maintenance of non-oxidative conditions were maintained (Guymon *et al.*, 1961). Fusel oil formation was the result of transamination of the corresponding amino acids due to which initially there were more alcohols, while with maturation these were used for ester formation, hence decreased (Zoecklein et al. 1995). Changes in higher alcohols content are desirable for better sensory properties of wines.

Volatile acidity (% A.A)

Table 4.3.8 shows that volatile acidity also changed significantly during maturation. In Camarosa and Chandler, it increased after maturation. However, Doughlas initially maintained the volatile acidity for 3 months, then it increased followed by a decrease. Initially, the highest volatile acidity was recorded in Chandler and it was similar after maturation. Among the treatments, there was also an increase in volatile acidity of various wines though maintaining the differences proportionately. However, the volatile acidity in different wines ranged between 0.024 to 0.032 per cent, indicating the soundness of wine during maturation. Among the interactions of cultivars and storage, there were significant differences. However, wines from Doughlas and Camarosa were found at par initially. Among the treatments and storage interaction (Fig. 4.3.3), wines made by normal fermentation and thermovinification were found at par at 6 and 9 month interval. The legal limit for volatile acidity in different wines is 0.12 per cent for red wines and 0.11 per cent for other wines (Amerine *et al.*, 1980). From this point of view, wines of all the treatments and cultivars fell within the range and is desirable. The increase in volatile acidity of wines might be due to oxidation of wine phenolics to yield peroxide which in turn oxidizes ethanol to acetaldehyde and subsequently, to acetic acid (Wildenradt and Singleton, 1974). The volatile acid content of less than 0.070 g/l seldom imparts spoilage character and in combination with low concentration of ethyl acetate may contribute to overall wine complexity (Zoecklein *et al.*, 1995).

Table 4.3.8 Changes in volatile acidity (% A/A) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	0.026	0.024	0.028	0.028	0.026	0.032	0.038	0.044	0.048	0.040	0.021	0.024	0.022	0.021	0.022	0.029
Thermovinification	0.027	0.028	0.029	0.034	0.029	0.027	0.032	0.029	0.035	0.030	0.032	0.037	0.026	0.028	0.0.30	0.030
Carbonic maceration	0.018	0.024	0.028	0.032	0.025	0.028	0.028	0.032	0.034	0.030	0.024	0.027	0.025	0.025	0.025	0.027
Fermented on the skin	0.021	0.024	0.025	0.036	0.026	0.025	0.026	0.032	0.037	0.030	0.018	0.027	0.028	0.026	0.024	0.027
Mean (VxM)	0.023	0.025	0.027	0.032		0.028	0.031	0.034	0.038		0.023	0.028	0.025	0.025		
Storage means (M)	0.024	0.028	0.029	0.031												
Cultivar means (V)	0.026	0.032	0.025													

CD ($P \geq 0.05$) Treatments(T) : 0.001, Cultivars(V) : 0.0006, Storage(M) : 0.001
TxV : 0.0008, VxM : 0.0008, TxVxM : 0.001

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Total esters

Table 4.3.9 show that total esters of different wines were significantly different during maturation. There was an increase in esters in wines of all the three cultivars and treatments during maturation. Further, the trend present initially was also maintained after maturation. Among the interactions, there were significant differences among wines made from different cultivars by different methods (Fig. 4.3.4). Increase in total esters during maturation is attributed to the phenomena of ageing (Amerine *et al.*, 1980) and is desirable for the development of proper flavour. The amount of total esters in various wines as summarized by Amerine (1954) varied between 200 to 400 mg/l. Esters in general, have fruity and floral impact characteristics that are important in sensory properties of wine. Wine esters may be formed as a result of reaction between acetate and ethanol as well as other higher alcohols. The other wine esters arise from ethanol by reaction with straight chain fatty acid precursors (Zoecklein *et al.*, 1995). Increases in ester content is desirable aspect of maturation as it increases the aroma and flavour notes of wines and hence acceptability.

Total phenols

Table 4.3.10 show that during maturation, a significant decrease in total phenols or tannins took place. There was also a decrease in phenol concentration during storage of wines of treatment and cultivar. Among the interactions, there were significant differences. Wines from cultivar Chandler and Doughlas were however, found at par during 9 months storage. However, among treatments (Fig. 4.3.4), there was significant difference during storage. Not only this, the trend observed initially remained after maturation also. Decrease in phenol concentration might be due to the susceptibility of phenolic constituents to degradation, condensation and polymerization and subsequent, precipitation (Beridze, 1948; Somers, 1987). During ageing, tannin levels in wines decreased as a result of oxidation and precipitation with proteins (Zoecklein *et al.*, 1995). The decrease in

Table 4.3.9 Changes in esters (mg/l) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	56	72	91	125	86	42	61	87	108	75	60	81	117	142	100	87
Thermovinification	60	82	99	136	94	45	67	89	116	79	63	80	124	148	104	92
Carbonic maceration	72	90	108	139	102	52	73	92	120	84	65	98	128	152	111	99
Fermented on the skin	51	69	89	116	81	40	69	88	103	75	60	78	105	141	96	84
Mean (VxM)	60	78	97	130		45	67	89	111		62	84	118	146		
Storage means (M)	56	77	101	129												
Cultivar means (V)	92	78	102													

CD ($P \geq 0.05$) Treatments(T) : 0.780, Cultivars(V) : 0.675, Storage(M) : 0.780
TxV : 0.954, VxM : 0.954, TxVxM : 1.91

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Table 4.3.10 Changes in phenol (mg/l) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	152	143	135	129	140	132	120	112	104	117	130	138	119	108	124	127
Thermovinification	168	152	143	138	150	150	140	132	128	137	162	150	142	130	146	145
Carbonic maceration	149	142	134	130	139	142	137	128	119	131	146	138	120	109	128	133
Fermented on the skin	164	155	145	137	150	149	132	129	123	133	159	147	139	128	143	142
Mean (VxM)	158	148	139	133		143	132	125	118		149	143	130	119		
Storage means (M)	150	141	131	124												
Cultivar means (V)	145	130	135													

CD ($P \geq 0.05$) Treatments(T) : 3.94, Cultivars(V) : 3.41, Storage(M) : 3.94
TxV : 4.82, VxM : 4.83, TxVxM : 9.66

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

total phenol is desirable as after their polymerization the palatability of the wine increases.

Anthocyanins

Table 4.3.11 show that anthocyanins contents of the wines were significantly decreased during maturation. The data further revealed that there was a decrease in anthocyanins in all cultivar wines. However, in matured wines the differences present initially were maintained. Initially, Camarosa had the highest anthocyanin and later on after maturation, it maintained the same trend. Similar trend was observed in different treatment wines. Control was recorded the highest anthocyanin before and after maturation. Among the interactions of cultivars and storage, there were significant differences. But wines from Chandler and Doughlas were found at par during 6 and 9 months of storage. However, among the treatments (Fig. 4.3.4), wines made by carbonic maceration, thermovinification and fermented on the skin were found at par during 6 and 9 months of interval. This might be due to the degradation and polymerization of anthocyanins easily with time. Similar to our findings, Pilando *et al.* (1985) reported that anthocyanins, the red pigments in raspberry and other fruits, degrade and polymerize easily with time. Rommel *et al.* (1990) also observed a 50 per cent loss of anthocyanin pigments after storage. But polymeric colour increased by 30 to 50 per cent after fermentation and increased further during storage.

Colour

Table 4.3.12 and 4.3.13 show the colour units of red and yellow in wine. With maturation the red colour units increased while yellow decreased. But after 6 months the red colour units were also decreased. Anthocyanin composition and content, cultivar maturity were found to influence the colour of red wine (Timberlake and Bridle, 1976). Jackson (1999) reported that as ageing progresses, colour becomes less intense, start to turn brickish and eventually becomes tawny. In

Table 4.3.11 Changes in anthocyanins (OD/ml wine) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	0.214	0.187	0.163	0.190	0.188	0.176	0.170	0.167	0.120	0.158	0.131	0.118	0.102	0.094	0.111	0.152
Thermovinification	0.178	0.132	0.120	0.101	0.132	0.168	0.147	0.125	0.108	0.137	0.112	0.101	0.094	0.080	0.097	0.122
Carbonic maceration	0.187	0.138	0.120	0.098	0.135	0.177	0.153	0.132	0.115	0.144	0.118	0.108	0.099	0.083	0.102	0.127
Fermented on the skin	0.190	0.158	0.129	0.103	0.145	0.186	0.152	0.120	0.119	0.144	0.128	0.115	0.103	0.089	0.108	0.132
Mean (VxM)	0.192	0.153	0.133	0.123		0.176	0.155	0.136	0.115		0.122	0.110	0.099	0.087		
Storage means (M)	0.163	0.139	0.122	0.108												
Cultivar means (V)	0.150	0.145	0.104													

CD ($P \geq 0.05$) Treatments(T) : 0.025, Cultivars(V) : 0.022, Storage(M) : 0.025
TxV : 0.031, VxM : 0.031, TxVxM : 0.063

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

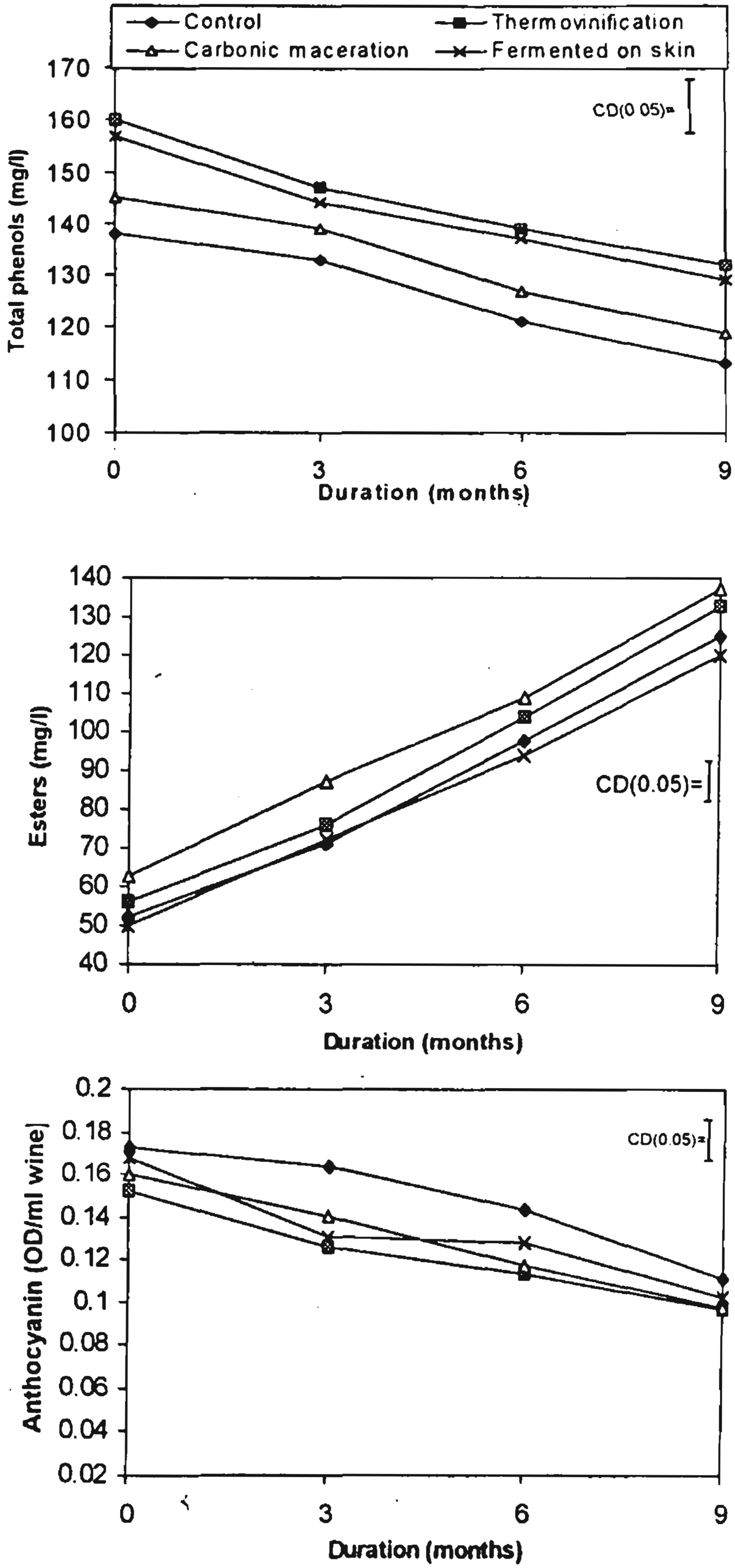


Fig. 4.3.4. Changes in phenol, esters and anthocyanins during maturation of different treatments strawberry wine

Table 4.3.12 Changes in colour units (red) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	12	20	16	16	16	12	11	12	15	13	8	10	5	4	7	12
Thermovinification	20	20	14	15	18	14	13	12	15	14	10	10	8	4	8	13
Carbonic maceration	15	15	10	13	14	11	13	5	5	9	8	10	8	4	8	10
Fermented on the skin	10	10	10	14	11	10	10	8	5	9	21	28	8	4	16	12
Mean (VxM)	15	17	13	15		12	11	10	10		12	15	8	4		
Storage means (M)	13	14	10	10												
Cultivar means (V)	15	10	10													

CD ($P \geq 0.05$) Treatments(T) : 1.11, Cultivars(V) : 0.96, Storage(M) : 1.11
TxV : 1.36, VxM : 1.36, TxVxM : 2.71

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

Table 4.3.13 Changes in colour units (yellow) during maturation of strawberry wine

Treatment	Varieties															Grand means (T)
	Camarosa					Chandler					Doughlas					
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	
Control	10	28	20	20	20	25	21	15	10	18	10	20	10	10	13	17
Thermovinification	10	25	15	10	15	28	20	10	10	17	24	11	10	10	14	16
Carbonic maceration	20	20	16	10	17	19	20	21	20	20	34	20	10	10	19	19
Fermented on the skin	20	20	18	16	19	29	21	20	20	22	20	20	12	6	15	19
Mean (VxM)	15	23	17	14		25	20	16	15		22	17	10	9		
Storage means (M)	21	20	15	12												
Cultivar means (V)	17	19	14													

CD ($P \geq 0.05$) Treatments(T) : 0.89, Cultivars(V) : 0.76, Storage(M) : 0.89
TxV : 1.07, VxM : 1.08, TxVxM : 2.17

Storage Interval = M_0 - Initial; M_1 - 3 months; M_2 - 6 months; M_3 - 9 months

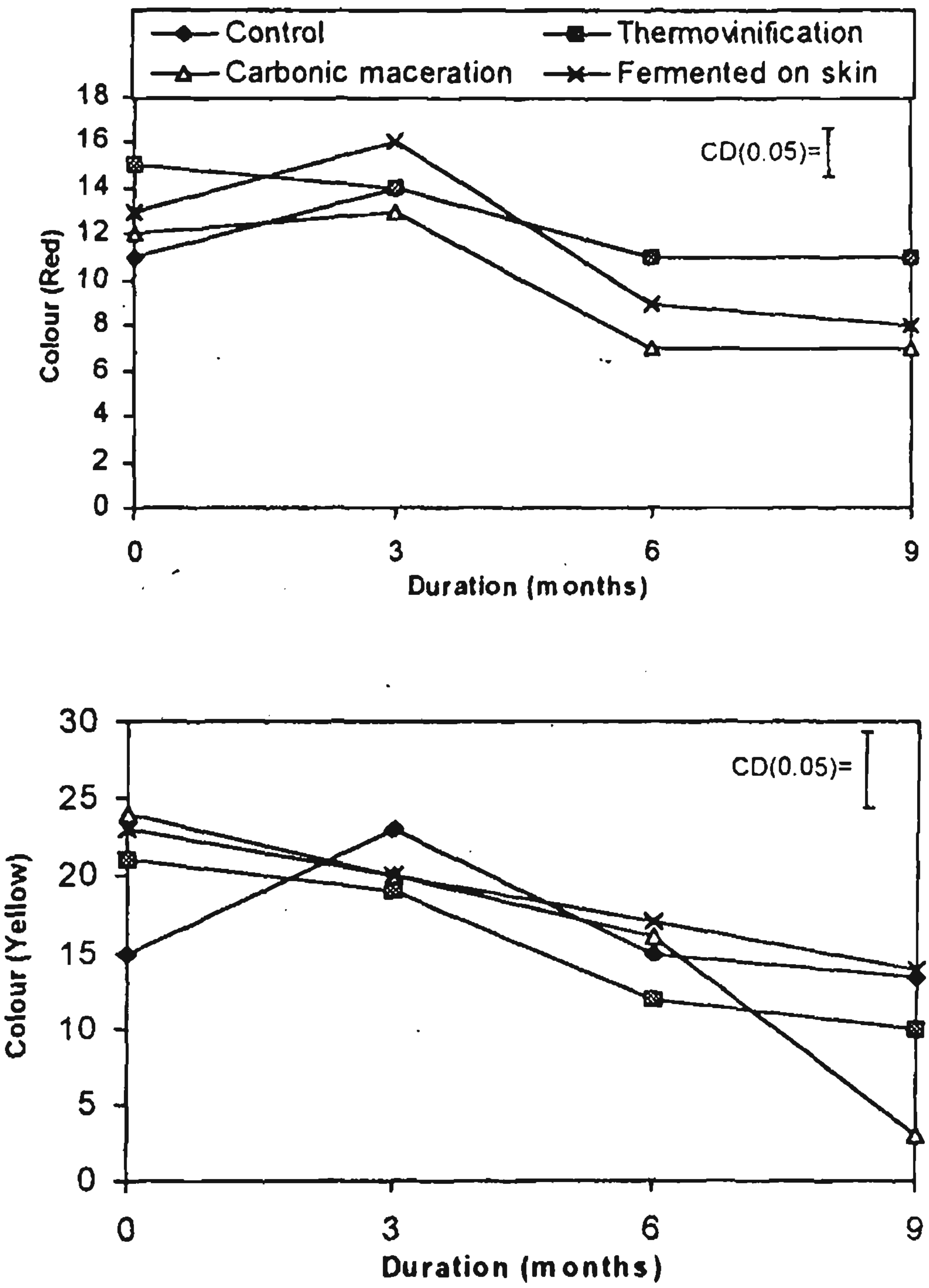


Fig. 4.3.5. Changes in colour (red and yellow) during maturation of different treatments strawberry wine

red wines, colour changes largely reflect the polymerization and oxidation of anthocyanins (Dallas *et al.*, 1995).

Microbial examination

The direct microbial examination of the wines of different treatments after 9 months of maturation indicated the presence of only few dead cells of yeast. Absence of bacteria indicates soundness of wines.

SENSORY EVALUATION OF WINES

Flavour profiling

The flavour profiling of the various treatments and cultivar wines by descriptive analysis (Table 4.3.14) show that flavour attributes like vegetative, alcoholic, fruity, vinegary, all spices like, earthy, bitterness, sweety, astringency, sour, yeasty, phenolic, higher alcoholic and strawberry like are the significant terms. The mean intensity ratings for the three cultivars and four treatments were plotted on a polar coordinate or "cobweb" graph (Fig. 4.3.6 and 4.3.7) using the fourteen descriptors which differed significantly across the cultivars and treatments. In this diagram, the centre of the figure represented low intensity with respect to each descriptor, increasing to an intensity of 6 at the ends of axes. The mean score for each descriptor for a specific wine is connected to give a sensory profile for each cultivar and treatment. Based on the Figure (4.3.6), Camarosa and Chandler were significantly higher than Doughlas for flavour intensities like alcoholic, vinegary, astringency, sour phenolic and strawberry like but lower than Doughlas for fruity and higher alcoholic whereas, all the three cultivars had the same intensity for yeasty. Chandler differed from Camarosa and Doughlas in higher intensity for bitterness, vegetative and earthy descriptors. However, Camarosa and Doughlas differed in the higher intensity in sweety descriptor.

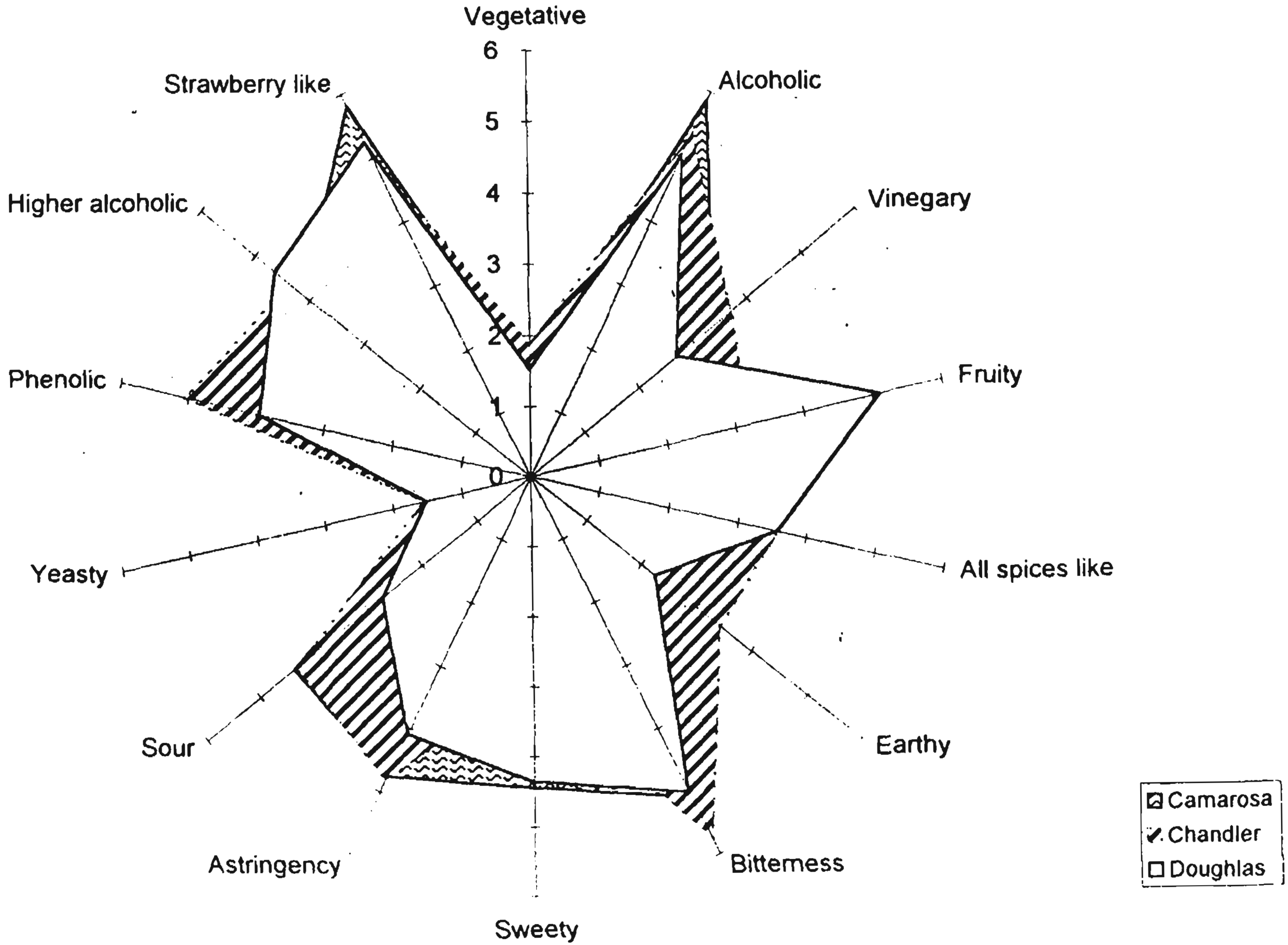


Fig. 4.3.6. Effect of varieties on flavour profiling of strawberry wine

Table 4.3.14 Details of descriptors and summary of analysis of variance of strawberry wines from different cultivars and treatments

No.	Descriptor	Standard	Treatment F value
1.	Vegetative	Shredded cabbage pieces	6.58*
2.	Alcoholic	Ethyl alcohol (8% v/v)	10.50*
3.	Vinegary	Vinegar diluted 25 times	4.69*
4.	Fruity	Raspberry essence	13.75*
5.	All spices like	Spices extract (diluted)	9.27*
6.	Earthy	Bentonite (0.5%)	10.20*
7.	Bitterness	Tea leaves extract	5.33*
8.	Sweety	Sugar solution (2%)	22.07**
9.	Astringency	Aonla extract	5.59*
10.	Sour	Citric acid (0.8%)	25.09**
11.	Yeasty	Fermenting must	5.33*
12.	Phenolic	Tannic acid (100 mg/l)	13.83*
13.	Higher alcoholic	Propyl alcohol (1%)	10.91*
14.	Strawberry like	Strawberry jams	10.34*

**Significant at 5% level of significance

* Significant at 1% level of significance

Among the treatments (Fig. 4.3.7), thermovinification and that fermented on the skin were significantly higher than carbonic maceration and the control for intensity of phenolic, higher alcoholic, strawberry like but lower than carbonic maceration for all spices like, bitterness, astringency and sour. Control wines differed from other three treatments in the higher intensity in vegetative, alcoholic and sweety descriptors and from that fermented on skin wines in significantly low intensity of earthy, bitterness and fruity. For rest of the descriptors, all the three cultivars and treatments were quite similar. Williams (1975) and Jarvis *et al.* (1995)

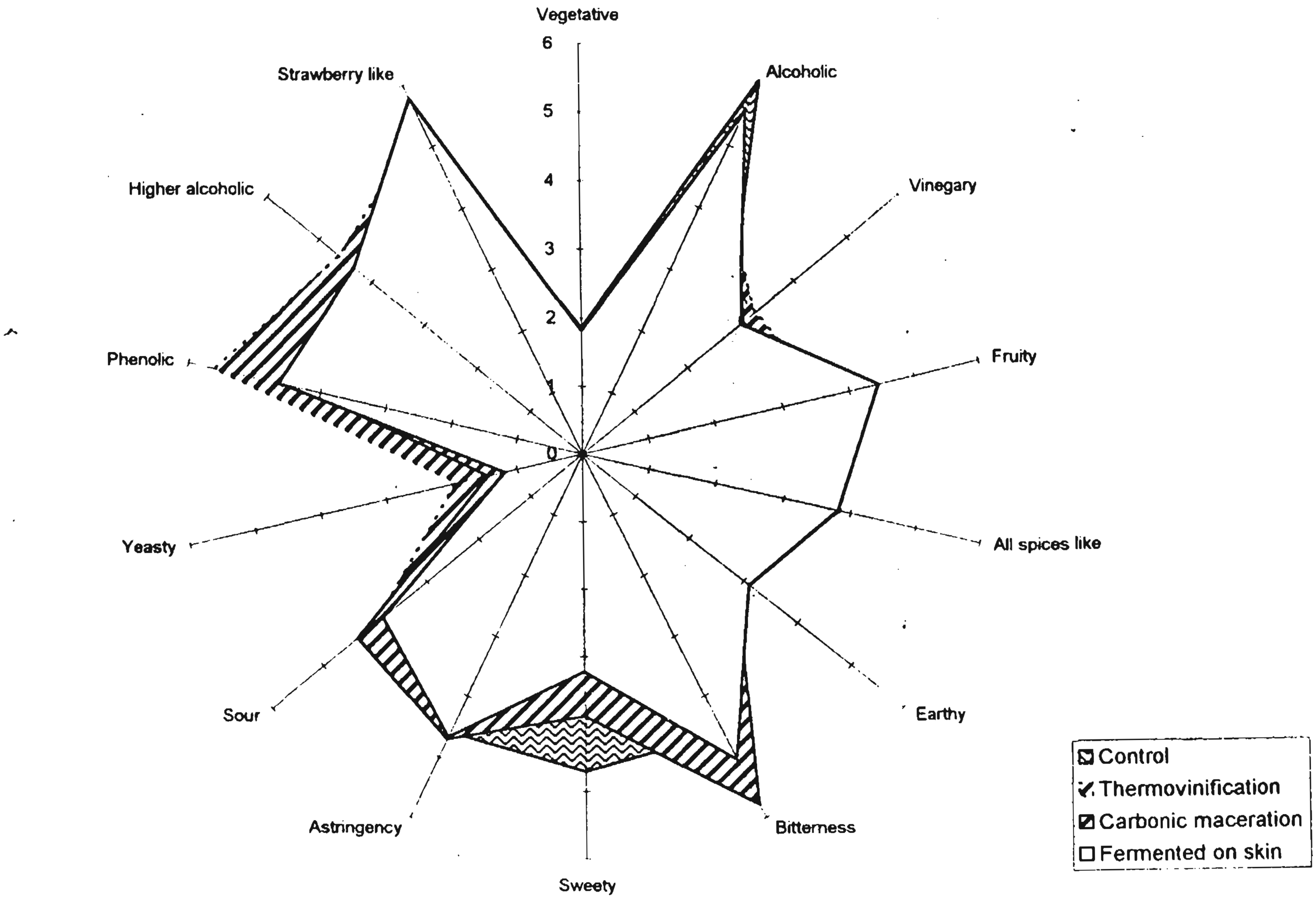


Fig. 4.3.7. Effect of treatments on the flavour profiling of strawberry wine

observed that the number of descriptors appears to be appropriate for flavour profiling of apple aroma which ranged from 50 to 80. However, red wines generally have fewer floral, citric, tree and tropical fruit odours and more berry like, dried fruit and woody characteristics (Duncan, 1995).

Principal Component Analysis

The Principal Component Analysis (PCA) of data obtained as means from flavour profiling using different descriptors was carried out. The PCA was performed without any rotation. Since 14 attributes cannot be conceived, the data reduction capabilities of PC analysis was employed to express the variance of these 14 attributes in four or five components. In explaining the results of PCA, the major axis or vector is called principal component I (PC I) and subsequent orthogonal axis are numbered (PC II or PC III). The attributes were plotted as vectors simultaneously with the wines of different cultivars and treatments. The length of vectors was interpreted as an indication of influence on that principal component. In Fig. 4.3.8 and 4.3.9, alcoholic, strawberry like, bitterness and phenolic have greater influence on the Principal Component I. Short vectors indicated attributes of relatively low importance whereas close alignment of a vectors with the principal component axis indicated a high correlation between the attributes represented by the axis and the variability explained by the principal component. From this point of view, higher alcoholic, earthy, sour, fruity, all spices like, astringency, vinegary have relatively lower intensity. The Eigen analysis of the output data showed that Ist PC accounted for maximum variation (71.7%) followed by PC II (11.2%) (Table 4.3.15). According to Kaiser criterion (Kaiser, 1960), PC I and PC II were the most important, followed by PC III. Perusal of Table 4.3.15 further showed that principal component I has eigen value of 8.602 and explains 71.7 per cent of variation in the data set and showed relatively maximum intensity for strawberry like, followed by alcoholic, bitterness, astringency, phenolic and higher alcoholic than the other attributes which were present in all the cultivars and treatment wines Therefore, it seems that strawberry like attribute had maximum influence on PC I.

Table 4.3.15. Summary of Eigen analysis

Eigen value	Per cent of trace	Accumulated per cent of trace
1 = 8.602	71.7	71.7
2 = 1.339	11.2	82.8
3 = 0.727	6.1	88.9
4 = 0.383	3.2	92.9
5 = 0.302	2.5	94.6
6 = 0.200	1.7	96.3
7 = 0.175	1.5	97.7
8 = 0.124	1.0	98.8
9 = 0.065	0.5	99.3
10 = 0.050	0.4	99.7
11 = 0.020	0.2	99.9
12 = 0.013	0.1	110.0

SPECIES COORDINATES (CORRELATIONS) ON THE FIRST THREE PRINCIPAL COMPONENTS

Species	Principal Component I	Principal Component II	Principal Component III
1 = Camarosa control	0.924	0.265	-9.059
2 = Camarosa thermovinified	0.980	0.077	-0.247
3 = Camarosa carbonic macerated	0.899	-0.289	-0.049
4 = Camarosa fermented on skin	0.864	0.120	-0.389
5 = Chandler control	0.885	-0.056	0.142
6 = Chandler thermovinified	0.863	-0.374	-0.040
7 = Chandler carbonic macerated	0.843	-0.288	-0.280
8 = Chandler fermented on skin	0.834	-0.398	0.059
9 = Doughlas control	0.559	0.764	-0.058
10 =Doughlas thermovinified	0.841	-0.094	0.343
11 =Doughlas carbonic macerated	0.870	0.425	0.077
12 =Doughlas fermented on skin	0.811	0.088	0.529

SAMPLING UNIT COORDINATES ON THE FIRST THREE PRINCIPAL COMPONENTS

Sampling Units	Principal Component I	Principal Component II	Principal Component III
Vegetative	-1.413	0.005	0.053
Alcoholic	1.004	0.247	-0.175
Vinegary	-0.507	-0.082	-0.025
Fruity	-0.024	0.382	0.453
All spice like	-0.244	-0.078	0.176
Earthy	-0.679	-0.249	-0.189
Bittemess	0.950	-0.286	0.060
Sweety	0.007	0.822	-0.371
Astringency	0.460	-0.099	-0.049
Sour	0.049	-0.324	-0.427
Yeasty	-1.506	-0.010	0.061
Phenolic	0.485	-0.418	0.029
Higher alcoholic	0.396	0.100	0.272
Strawberry like	1.022	-0.001	0.127

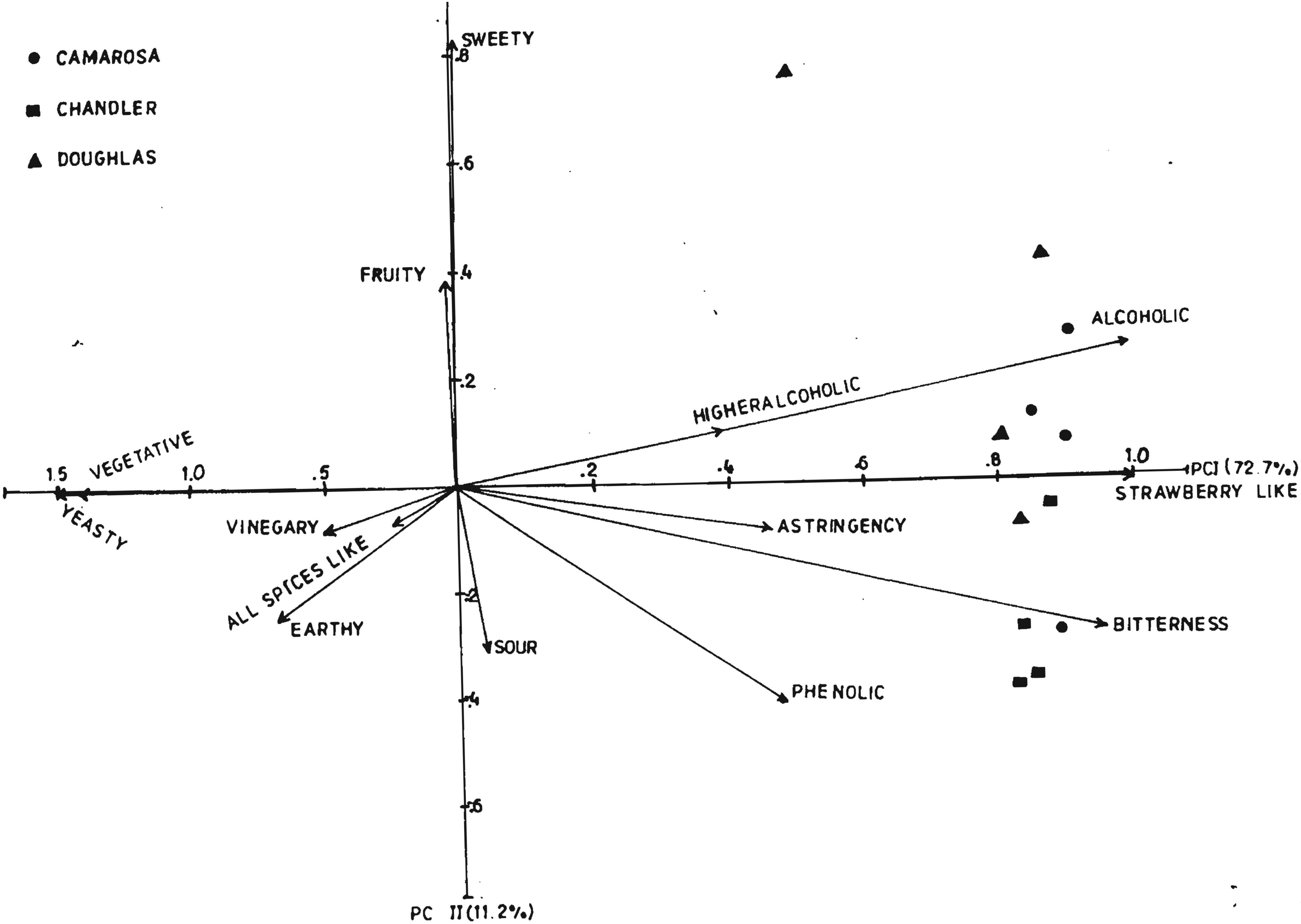


FIG. 43.8 PROJECTION OF FLAVOURING DATA OF STRAWBERRY WINES OF DIFFERENT CULTIVARS IN PCA'S IN PLANES DEFINED BY PRINCIPAL COMPONENT 1 AND 2.

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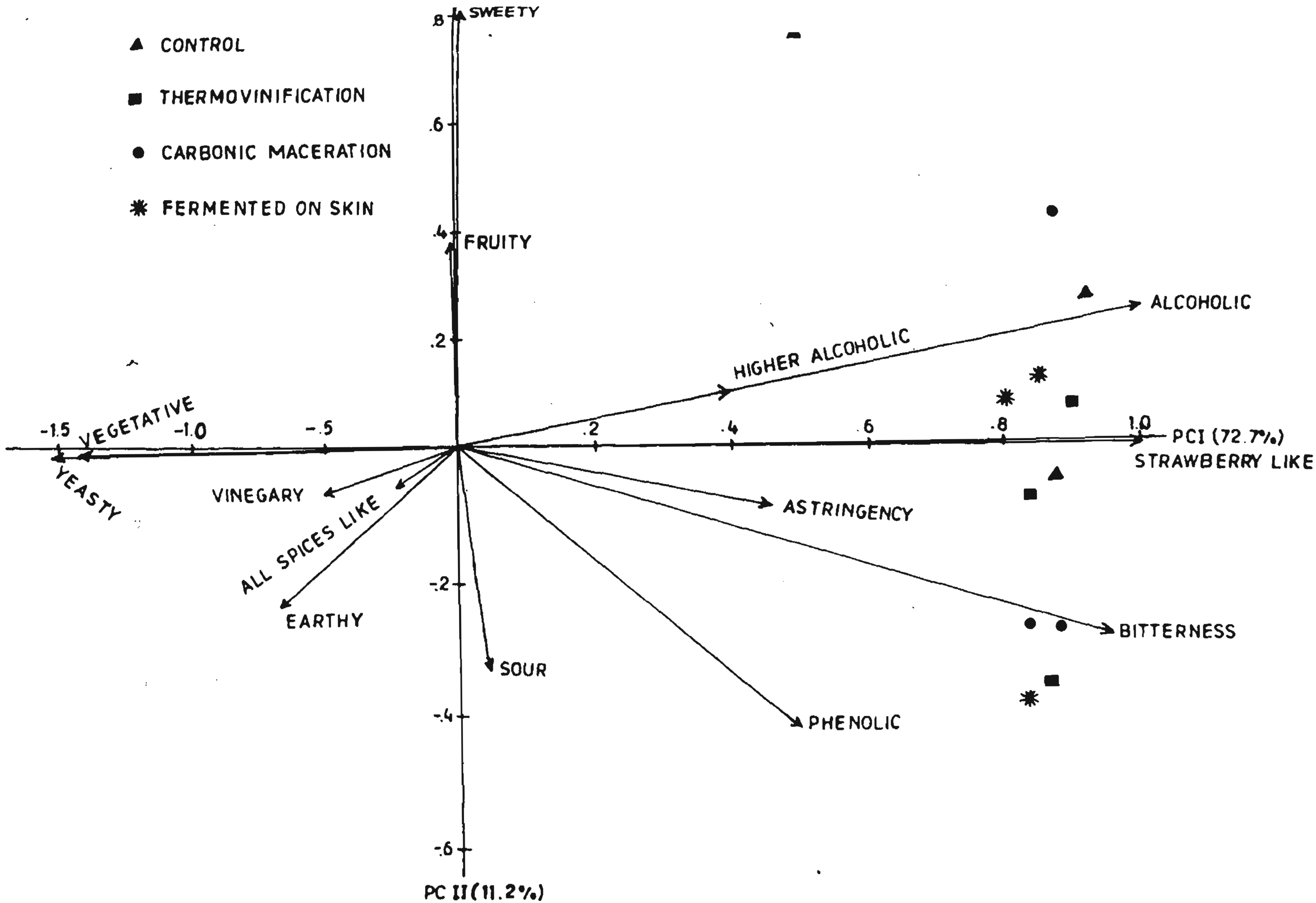

FIG. 43.9 PROJECTION OF FLAVOURING DATA OF STRAWBERRY WINES OF DIFFERENT TREATMENTS IN PCA'S IN PLANES DEFINED BY PRINCIPAL COMPONENT 1 AND 2.

And the second principal component, with eigen value 1.339 explains 11.2 per cent of total variation and ranking the attribute 'sweety' as number one, because it showed the maximum contribution of this very variable. In Fig. 4.3.8 and 4.3.9 PC I and PC II were plotted with 14 attributes as vectors loading simultaneously with the different cultivar wines or the treatments. PCI was defined by the characters like alcoholic, strawberry like, bitterness, astringency, higher alcoholic which were present in all the cultivars and treatment wines except for carbonic macerated Camarosa cultivar wine. Yeasty, vegetative, vinegary, all spices like attributes were also defined by PCI but in opposite direction, denoting these were negatively correlated of the order 0.024, 1.413, 0.507 and 0.244, respectively. It can be seen from the Fig. 4.3.8 and 4.3.9 that the wines have separated along the first PC according to the intensity of their alcoholic, strawberry like, astringency and bitterness. The intensity of their phenolic aroma also contributes to the separation of the wines but to a lesser extent. It is also clear from the Figures 4.3.8 and 4.3.9 that the PCA has weekly separated the wines of different treatments than cultivars. Therefore, we can say that cultivar has greater effect on flavour quality of wine than the method of vinification.

Sensory evaluation

The results on sensory analysis of strawberry wine of different cultivars presented in Table 4.3.16 show that there were significant differences among the cultivars for different quality attributes. A perusal of the data further revealed that Camarosa cultivar wine was superior in most of the quality attributes except for volatile acidity, total acidity and bitterness. Further, out of the three wines, Camarosa wine was superior mainly because of better colour, aroma, appearance, sweetness, flavour, body, astringency and better over-all acceptability. However, it was found to be at par with Chandler cultivar for total acidity and astringency. The total score of wines of different cultivar (out of 20) in Fig. 4.3.10 indicate that all the wines were having commercial acceptability as their scores were more than 13.

Table 4.3.16. Comparison of sensory scores of strawberry wines from different cultivars

Attributes	Maximum score	Camarosa (Mean)	Chandler (Mean)	Doughlas (Mean)	CD≥0.05
Colour and depth	2.0	1.35	1.26	1.12	0.029
Aroma and bouquet	4.0	3.65	3.49	3.32	0.026
Appearance	2.0	1.59	1.35	1.32	0.016
Volatile acidity	2.0	1.44	1.53	1.31	0.020
Total acidity	2.0	1.57	1.58	1.61	0.018
Sweetness	1.0	0.72	0.65	0.67	0.008
Body	1.0	0.72	0.68	0.64	0.008
Flavour	2.0	1.69	1.57	1.53	0.015
Bitterness	1.0	0.65	0.59	0.67	0.006
Astringency	1.0	0.74	0.74	0.57	0.007
Overall acceptability	2.0	1.71	1.69	1.63	0.007
Total score	20	15.83	15.13	14.39	
CD (P≥0.05) (Total score)		0.064			

Scale - According to Amerine *et al.* (1968)
Ratings - Superior : 17-20, Standard : 13-16, Below standard : 9-12, Unacceptable : 1-8

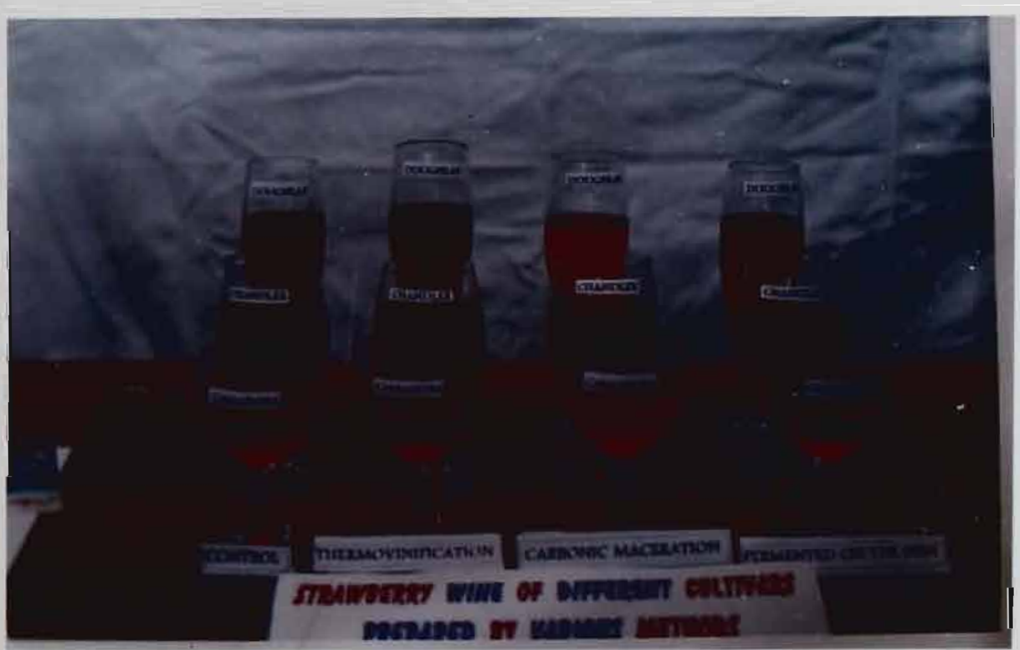

Plate 4.3.1. Comparison of strawberry wines during and after 9 months maturation

Among the treatments, it is discernible from the data (Table 4.3.17) that there were significant differences among the treatments for different attributes except for total acidity, sweetness and over-all acceptability, whereas thermovinified wines were at par with those fermented on the skin for total acidity. Control wines were found at par with carbonic macerated wines for sweetness and in over-all acceptability. Carbonic macerated wines were observed at par with fermented on skin wines. A perusal of the data further indicates that thermovinified wines were superior in most of the quality attributes except for aroma, total acidity, bitterness and astringency where carbonic macerated wines were rated higher scores. Further, out of four different methods of wine preparation, thermovinified wines were rated superior because of better colour, appearance, volatile acidity, sweetness, body and overall acceptability. The total scores (Fig. 4.3.11) indicated that all the wines were having commercial acceptability but thermovinified wines were adjudged to be the best. Plate 4.3.1 show the wines of different treatments and cultivars comparison during maturation studies and after 9 months maturation. High temperature fermentations were reported to increase the total extraction of phenolic compounds that may have made impact on both colour and flavour (Girard *et al.*, 1997). Thus, by selecting a proper method for vinification, the wine of superior quality can be made from strawberry fruits.

Sensory evaluation after maturation

It is discernible from the Table 4.3.18 that after maturation of 9 months all the wines were awarded higher scores for each attribute than their initial scores. There were significant differences between the initial scores and final scores of wines. A perusal of the data however, revealed that there was a decrease in colour scores and that might be due to browning of the wines as described earlier also. The scores (Fig. 4.3.12) also revealed that wines have been adequately improved after 9 months of maturation.

During ageing, as discussed earlier that there was a decrease in tannin, anthocyanin and total sugar contents whereas an increase was observed in total

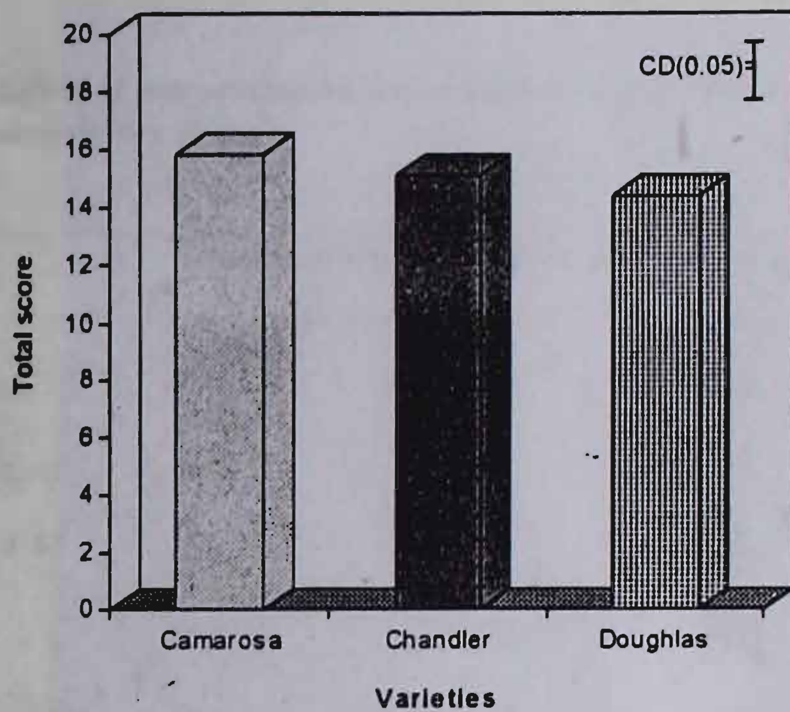

Fig. 4.3.10. Overall scores of different strawberry cultivar wines (out of 20)

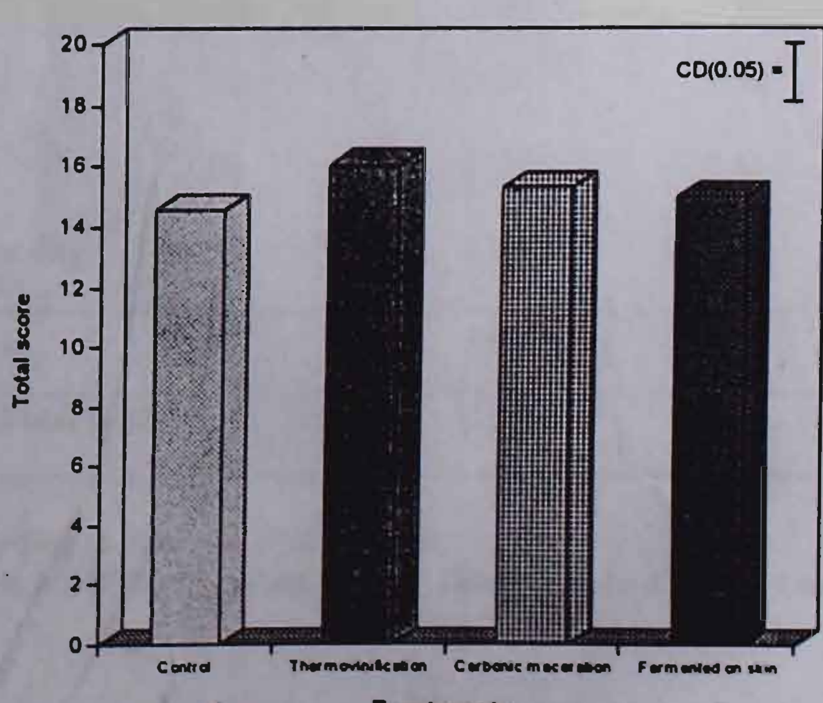

Fig. 4.3.11. Overall scores of different treatment wines (out of 20)

Table 4.3.17. Comparison of sensory scores of strawberry wines of different treatments

Attributes	Treatments (Mean score)					
	Maximum score	Control (T_1)	Thermo-vinification (T_2)	Carbonic maceration (T_3)	Fermented on the skin (T_4)	CD≥0.05
Colour and depth	2.0	1.35	1.51	1.15	1.40	0.034
Aroma and bouquet	4.0	3.42	3.58	3.72	3.46	0.030
Appearance	2.0	1.42	1.58	1.39	1.29	0.018
Volatile acidity	2.0	1.49	1.53	1.36	1.32	0.023
Total acidity	2.0	1.57	1.55	1.70	1.54	0.013
Sweetness	1.0	0.68	0.71	0.68	0.66	0.009
Body	1.0	0.58	0.74	0.70	0.68	0.009
Flavour	2.0	1.24	1.75	1.57	1.63	0.017
Bitterness	1.0	0.57	0.68	0.70	0.68	0.007
Astringency	1.0	0.64	0.66	0.68	0.67	0.008
Overall acceptability	2.0	1.62	1.76	1.66	1.66	0.007
Total score	20	14.58	16.05	15.31	14.99	
CD (P≥0.05) (Total score)		0.075				

Scale - According to Amerine *et al.* (1968)

Ratings - Superior : 17-20, Standard : 13-16, Below standard : 9-12, Unacceptable : 1-8

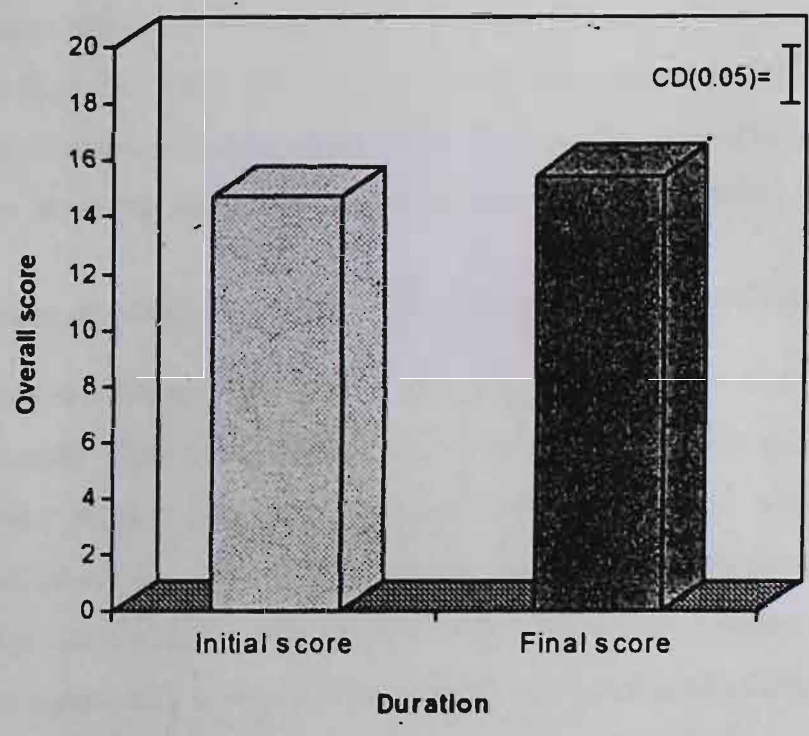

Fig. 4.3.12. Effect of maturation on the overall sensory scores (out of max 20) of strawberry wines

Table 4.3.18. Effect of maturation on the sensory scores of various attributes of strawberry wines

Attributes	Maximum score	Initial score	Final score	CD≥0.05
Colour and depth	2.0	1.29	1.20	0.024
Aroma and bouquet	4.0	3.42	3.57	0.021
Appearance	2.0	1.34	1.39	0.081
Volatile acidity	2.0	1.34	1.52	0.016
Total acidity	2.0	1.53	1.65	0.018
Sweetness	1.0	0.62	0.74	0.006
Body	1.0	0.64	0.72	0.006
Flavour	2.0	1.49	1.70	0.012
Bitterness	1.0	0.68	0.58	0.005
Astringency	1.0	0.72	0.61	0.005
Overall acceptability	2.0	1.64	1.72	0.005
Total score	20	14.7	15.4	
CD (P≥0.05) (Total score)		0.079		

Scale - According to Amerine *et al.* (1968)
Ratings - Superior : 17-20, Standard : 13-16, Below standard : 9-12, Unacceptable : 1-8

esters, higher alcohols, reducing sugar and pH. The changes have been reflected in sensory quality of the different wines. Amerine *et al.* (1980) reported that as the wine ages properly, the harsh taste and yeasty odour diminish and a smooth mellow flavour and clean odour are produced.

From the maturation study, it is inferred that maturation for 9 months altered various components of strawberry wine like esters, phenols, higher alcohols which are desirable from the sensory quality point of view. Other parameters like volatile acidity, titratable acidity, TSS, pH and reducing sugars, total sugars virtually remained unaffected in terms of their absolute values. These parameters however, remained within the limit. Further, the results also suggest that wine remained in the satisfactory conditions during maturation. Moreover, these changes were similar to those which occur for any other wine during maturation (Jackson, 1999).

Identification of phenolic compounds and separation in different wines

Table 4.3.19 summarizes the type of phenols in wines of different cultivars and treatments. The phenols detected in all cultivars were catechin, epicatechin, quercitin and ellagic acid. But quercitin and ellagic acid were found absent in thermovinified wines. Quercitin was not found in Doughlas cultivar wine also which is fermented on the skin. But there was no difference in wines for other phenols. Difference in phenols in various wines might be traced to the difference in cultivar or their amount in wine might be low which could not have been detected by TLC.

There is no report on type of the phenols present in strawberry wine. However, in strawberry fruits, ellagic acid, catechin, epicatechin and quercitin have already been reported (Daniel, 1989; Mass *et al.*, 1991). In peach wine phenolics like epicatechin, gallic acid and leucoanthocyanin have been reported by Joshi *et al.* (1999). Osawa *et al.* (1987) and Su *et al.* (1988) have reported that ellagic has a function as an antioxidant. Mass *et al.* (1991) reported ellagic acid as an anti-carcinogenic plant phenol, including its inhibitory effects on chemically induced cancer.

Table 4.3.19. Identification of phenol components in strawberry wine

Type of phenols	Rf	Control	Thermovinified wines	Fermented on the skin	Carbonic maceration
Catechin	0.48	+1 to 3	+1 to 3	+1 to 3	+1 to 3
Epicatechin	0.54	+1 to 3	+1 to 3	+1 to 3	+1 to 3
Quercitin	0.70	+1 to 3	-	+2 and 1	+1 to 3
Ellagic acid	0.68	+1 to 3	-	+1 to 3	+1 to 3

+ : Present, - : Absent

1 : Camarosa, 2 : Chandler, 3 : Doughlas

The presence of phenolics in wines is of paramount importance and has profound implications in human health due to recently discovered role of phenolics as an antioxidant (Muller, 1995; Joshi *et al.*, 1999). Antioxidants exert beneficial effect by preventing the action of free radicals in human body and thus, prevent the occurrence of deadly diseases like cancer, specially the coronary heart diseases (Kinsella *et al.*, 1993) at lower concentrations. In grape wine, the consumption of red wine has reduced the incidence of coronary heart disease (CHD) apparently due to the presence of phenolic compounds. From this point of view, strawberry wine could also have similar health implications as that of grapes.

4.4 ECONOMIC EVALUATION OF THE STRAWBERRY WINE PRODUCTION

Cost of production

The data on the cost of production which was worked out on the basis of current market price of ingredients, containers, closures used and processing cost, besides incorporating overhead charges (office expenses, stationary, advertisement, breakage etc.) profit margins and excise duties are given in Table 4.4.1).

A comparison of the total cost of wines of different cultivars revealed clearly that Camarosa cultivar wine had the highest cost of production while the Doughlas had the lowest. However, wine prepared from Chandler cultivar was cheaper than others due to lower fruit cost and better physico-chemical characteristics. Among the treatments, thermovinification and fermentation on the skin were cheaper in comparison to carbonic maceration. The higher cost of wine from Camarosa cultivar is apparently due to the higher cost of fruits of this cultivar, should not be taken as disadvantage. Since the area is increasing under strawberry cultivation, so in near future one would be able to get the fruits at low cost.

A survey of cost of different wines in market would emphatically reveal that even the highest cost of wine obtained in this study is not high since in India good

Table 4.4.1 Cost of production of strawberry wines of different cultivars prepared with best method

Items	Varieties								
	Camarosa			Chandler			Doughlas		
	Quantity	Rate	Amount	Quantity	Rate	Amount	Quantity	Rate	Amount
Cost of fruits	10 kg	Rs.100/kg	Rs.1000/-	10 kg	Rs.35/kg	Rs.350/-	10 kg	Rs.60/kg	Rs.600/-
Cost of sugar	4 kg	Rs.17/kg	Rs.68/-	4.5kg	Rs.17/kg	Rs.76.50	4.9 kg	Rs.17/kg	Rs.83.30
Cost of DAHP	10gm	Rs.300/kg	Rs.3/-	10gm	Rs.300/kg	Rs.3/-	10gm	Rs.300/kg	Rs.3/-
Cost of pectinol	30gm	Rs.800/kg	Rs.24/-	30gm	Rs.800/kg	Rs.24/-	30gm	Rs.800/kg	Rs.24/-
Cost of KMS	1gm	Rs.280/kg	Paise 28	1gm	Rs.280/kg	Paise 28	1gm	Rs.280/kg	Paise 28
Bottles required	17 Nos.	Rs.3/bottle	Rs.51/-	16 Nos.	Rs.3/bottle	Rs.48/-	16 Nos.	Rs.3/bottle	Rs.48/-
Crown corks	17 Nos.	Paise 30	Rs.5.10	16 Nos.	Paise 30	Rs.4.80	16 Nos.	Paise 30	Rs.4.80
Total			**Rs.1151.38**			**Rs.506.58**			**Rs.763.38**
Overhead charges @ 20% (office)			Rs.230.27			Rs.101.31			Rs.152.67
Processing charges @ 20%			Rs.230.27			Rs.101.31			Rs.152.67
Additional charges @ 10% on fermentation			Rs.115.13			Rs.50.63			Rs.76.33
Depreciation of machinery & equipments@ 10%			Rs.115.13			Rs.50.63			Rs.76.33
Excise duty* Rs.2.60 per bottle			Rs.44.20			Rs.41.60			Rs.41.60
Total			**Rs.1886.38**			**Rs.852.06**			**Rs1262.98**
Profit margins 25%			Rs.471.59			Rs.213.00			Rs.315.75
Grand total			**Rs.2357.97**			**Rs.1065.07**			**Rs1578.72**
Cost per unit bottle (650 ml)			Rs.138.70			Rs.67.00			Rs.98.67
Wine recovery	72%			70%			68%		

*Source : Office of Excise & Texation Officer, Solan,H.P; Cost of bottle is included in the cost estimation house wines are available at star hotels which are quite expensive, with cost ranging from Rs.600/- to Rs.800/- a bottle (Sunday Times of India, 7th May, 2000). So by following method of wine preparation developed and evaluated in this study, we would be able to provide good wine to the wine connoisseurs. Nevertheless, the cost of production of fruit based low alcoholic beverage needs to be brought down so as to bring them within the reach of customers.

Chapter 5

SUMMARY & CONCLUSIONS

Investigations entitled "Preparation and Evaluation of Strawberry Wine" were carried out to determine the suitability of different strawberry cultivars for wine preparation, standardization of methods of preparation of strawberry wine and to monitor the changes during maturation of the product. Strawberry fruits of cultivar Camarosa and Doughlas were brought from Chandigarh and Una fruit markets. Whereas, cultivar Chandler was brought from University Orchard of Department of Pomology, UHF, Nauni. The four methods viz. control, thermovinification, carbonic maceration and fermented on the skin were employed for fermentation. The wines after preparation were matured for a period of 9 months, recording observations after every 3 months to determine the changes during maturation. The following conclusions were drawn from these studies:

1. On the basis of physico-chemical characteristics viz. size of the fruit, weight, pulp, TSS, titratable acidity, total and reducing sugars, the cultivar Camarosa was found superior to Chandler and Doughlas.

2. The must of cultivar Chandler gave the highest rate of fermentation and ethanol content. Among the treatments that fermented on the skin gave the highest rate of fermentation and ethanol content.

3. Strawberry wine from cultivar Camarosa and Chandler were found to have higher total soluble solids, total sugars, reducing sugars, phenols, titratable acidity, volatile acidity, anthocyanin, alcohol and higher alcohol than Doughlas, while the lowest esters were recorded in cultivar Chandler

4 Among the treatments, thermovinification was considered better than the control with respect to the highest volatile acidity, phenols, titratable acidity and lowest reducing sugars, anthocyanin, ethanol content. Carbonic maceration followed thermovinification with highest pH, ethanol, esters and lowest acidity.

5. Flavour profiling of wines of different cultivars revealed that out of 14 descriptors, 6 had very high intensity which were strawberry like, alcoholic, phenolic, higher alcoholic, astringency and bitterness. However, vegetative, yeasty and earthy were found to have lower intensity. Among the treatments out of 14 descriptors, 6 had very high intensity which were strawberry like alcoholic, bitterness, phenolic, astringency and higher alcoholic.

6. From the sensory quality point of view, the wines of all the cultivars were acceptable but that of Camarosa was rated the best. Among the treatments, thermovinified wines were rated the best.

7. Different phenolic compounds viz. catechin, epicatechin, quercitin and ellagic acid were identified by TLC. Since these phenolic compounds have antioxidant property, strawberry wine could provide these antioxidants to the consumers.

8. Maturation studies of wines of different cultivars and treatments revealed that there was increase in reducing sugars, esters and volatile acidity. But a decrease was observed in TSS, total sugars, titratable acidity, colour, anthocyanins and total phenols. These changes were considered desirable for increasing the palatability of strawberry wine.

9. Cost of production of strawberry wine was found to be higher than other fruit wines. But in comparison to the prevailing market rates, the strawberry wines are still cheaper.

In brief, amongst the cultivars tried, Camarosa and Chandler can successfully be used for wine preparation. Thermovinification followed by fermented on the skin proved better methods for production of good quality wines. Maturation of minimum 9 months should be given to strawberry wine for improvement in quality. Among the different cultivars, Camarosa wine was found the best in sensory quality and between the treatments, thermovinification was the best. Presence of phenolic compounds such as ellagic acid, catechin increases the medicinal value of strawberry wine. It can be concluded that strawberry fruits hold promise for preparation of quality wine by the variety evaluated and the method standardized.

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* *Original not seen*

ANNEXURE –I
NUMERICAL SCORING CARD

Product : **Strawberry wine**
Product volume : **200 ml**

CHARACTERISTICS

	Appearance	Colour and depth	Aroma and bouquet	Volatile acidity	Total acidity	Sweetness	Body	Flavour	Bitterness	Astringency	Overall impression	Total
Max. score	2	2	4	2	2	1	1	2	1	1	2	20
T_1B_1												
T_2B_1												
T_3B_1												
T_4B_1												
T_1C_1												
T_2C_1												
T_3C_1												
T_4C_1												
T_1D_1												
T_2D_1												
T_3D_1												
T_4D_1												

Comments :
Special observation :

Signature
Name and Designation

ANNEXURE –II

ASSESSMENT OF AROMA AND MOUTH FLAVOUR OF WINE (DESCRIPTIVE PROFILLING OF STRAWBERRY WINE)

NAME
DATED

Using the 9 point intensity scale shown below. Rate each sample for all attributes listed below.

FOR AROMA AND MOUTH FEEL

1=None, 2= Threshold, 3= Slight, 4= Slight to moderate, 5= Moderate, 6= Moderate to large, 7=Large, 8 = Large to extreme and 9 = Extreme to large.

	T_1B_1	T_2B_1	T_3B_1	T_4B_1	T_1C_1	T_2C_1	T_3C_1	T_4C_1	T_1D_1	T_2D_1	T_3D_1	T_4D_1
1. Vegetative												
2. Alcoholic												
3. Vinegary												
4. Fruity												
5. All spices like												
6. Earthy												
7. Bitterness												
8. Sweety												
9. Astringency												
10. Sour												
11. Yeasty												
12. Higher alcoholic												
13. Phenolic												
14. Strawberry like												

Signature of Evaluator
Name :
Address :

CURRICULUM VITAE

Name : Somesh Sharma

Father's Name : Sh. Kailash Sharma

Date of Birth : 02.03.1976

Sex : Male

Marital Status : Unmarried

Nationality : Indian

Educational Qualifications :

Certificate/ Degree	Class/ Grade	Board/University	Year
Matric	First	CBSE	1992
Higher Secondary	First	CBSE	1994
B.Sc. Horticulture	First	UHF, Nauni, Solan	1998

Whether sponsored by some state/ Central Govt./Univ./SAARC : No

Scholarship/ Stipend/ Fellowship, any other financial assistance recieved during the study period : M.Sc. - University Stipend

Title of thesis	:	Preparation and evaluation of strawberry wine
Name of student	:	Somesh Sharma
Admission No.	:	H-98-36-M
Degree awarded	:	M.Sc. Horticulture (Postharvest Technology)
Name of major advisor	:	Dr V.K.Joshi (Assoc. Professor)
Major field	:	Postharvest Technology
Minor field(s)	:	i) Biochemistry ii) Microbiology
Number of pages in thesis	:	83+xi+II
Year of award of degree	:	2000
Number of words in Abstract	:	267

ABSTRACT

Strawberry (Fragaria ananassa), a highly perishable fruit grown in Himachal Pradesh. The fruit is bestowed with an attractive colour, flavour and taste and can be utilized in preparation of alcoholic beverages. The objectives of present investigations were to standardize the technique for quality strawberry wine preparation, to screen the variety suitable for strawberry wine, to study the changes occuring in wine during maturation and to work out the economics of products. Fruits of three cultivars Camarosa, Chandler and Doughlas were employed. Wines were prepared by four methods, control, thermovinification, fermented on the skin and carbonic maceration. Amongst the cultivars evaluated, cultivar Camarosa and Chandler can successfully be used for wine preparation as the wines from these cultivars had better physico-chemical and sensory quality characteristics than Doughlas. Among the treatments, thermovinification was best followed by carbonic maceration. Flavour profiling of wines of different treatments and cultivars revealed that out of 14 descriptors, 6 had very high intensity (strawberry like, alcoholic, bitterness, astringency, phenolic and higher alcoholic). Presence of different phenolic compounds such as ellagic acid, quercitin and catachin could provide antioxidant property to the wines. Maturation studies of strawberry wines revealed that maturation of minimum 9 months should be given to the strawberry wine for improvement in quality and the changes occurring during maturation, considered desirable for improvement. Cost of production of strawberry wine was found to be higher than other fruit wines. But in comparison to prevailing market rates, the strawberry wines are still cheaper. It can be concluded that strawberry fruits hold promise for preparation of quality wine by the variety evaluated and the method standardized.

Signature of the student **Major Advisor**

Countersigned

Professor and Head
Department of Postharvest Technology
University of Horticulture and Forestry
Nauni, Solan (HP)