Flavour of wine treated with toasted New Zealand woods

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Ishita Mahajan
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Table of Contents

Abstract

The traditional wood used to make barrels destined for use in the world wide wine industry is oak. However, oak chips and shavings can substitute for barrels to add flavour to wine and are very much more cost effective. As with the heat treatment of barrels, oak chips are toasted before use. This serves to pyrolyse lignin and hemicellulose, generating families of compounds that impart desirable flavours to wine. Other woods are very occasionally used in wine barrel construction, but no chips other than oak chips have been used to flavour wine. This is surprising given that all woods contain lignin and hemicellulose, the composition of which will vary perhaps usefully from species to species.

The 12 woods used in this research, including American oak, were chosen on several criteria: botanical similarly to oak, exclusivity to New Zealand, and historical association with New Zealand. The woods were cut to chips measuring about 10 x 20 x 2.5 mm. The moisture content was measured after dry heating to 110°C. Fresh samples of chips were heated (toasting in the context of wine) to 200°C for 2 hours, 210°C for 3 hours, called light and heavy toasting respectively. Weight loss was determined. The colour of the untreated and toasted wood chips was measured in Hunter colour space, yielding data on lightness (L*), hue angle (the basic colour) and saturation (the intensity of colour).

The moisture content of oak was the lowest of all the woods. The weight loss of oak chips at 200°C was much greater than that of other woods, but the colour change did not indicate losses due to severe charring. Overall, each wood behaved in a distinctive way to the toasting treatments, with some charring much more than others. Hue was the least affected, indicating that the basic colour of the woods was little changed by toasting. Light and saturation generally decreased strongly, particularly on heavy toasting. Colour was thus being lost and less light reflected.

An unoaked chardonnay was infused with toasted chips at the rate of 5 $g.L^{-1}$ for two weeks at room temperature, and later decanted. At all stages exposure to air was minimised.

The 25 treatments (2 x 12 plus the unwooded control) were first assessed by a panel comprising eight experienced wine tasters and 29 AUT staff members who claimed some knowledge of wine flavour. This qualitative/semi-quantitative analysis required tasters to assess the wines in terms of 12 descriptors commonly associated with oaked wines (boxes were ticked for ‘sweet oak’, ‘smokey’, ‘vanilla’ etc.), and to choose the three most liked and the three least liked.

A principal component analysis of a correlation matrix of descriptors was used to summarise panelist's opinion. The first two principal components explained 53 % of the variation and served to group descriptors into four quadrants, which were each associated with different woods and toasting levels. Most liked were totara light (toast), kahikatea heavy, manuka heavy and American oak light. Macrocarpa light toast was almost universally disliked.

On the basis of liking and association with New Zealand, five woods and chosen toasting levels and the control were selected for hedonic trials (1 to 9 liking scale) with 180 consumers (age range and gender were identified) in six retail wine shops. The decreasing numerical of liking by treatment was totara (6.49), control, manuka, American oak, kahikatea, radiata pine (5.47), with an overall significant effect ($P < 0.001$) for treatment. Tukey's test revealed that only totara and the control treatments were outstanding ($P < 0.05$). Retail wine shop as a factor was marginally significant. Older consumers liked the wines more ($P < 0.05$), as did females ($P < 0.001$). There were no significant interactions between any of the factors.

Because of the difficulties in sourcing totara, manuka appears to be the most viable alternative to oak as a wine flavouring in the New Zealand context.

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Thanks go to Mr. Andrew Vincent of South Pacific Timber, Eden Terrace, for the supply of wood, and to Mr. Simon Nunns of Coopers Creek Vineyard Limited for the supply of the 2005, unoaked, Gisborne chardonnay. Big thanks to Mr. Jeff Poole and Mr. Brett Taylor of The Fine Wine Delivery Company for letting me to carry out the sensory tastings in their shop. Big thanks also go to six suburban wine shops for allowing me to carry out the second half of my wine tastings. Thanks also go to my supervisor Dr. Owen Young, who was the inspiration for this work.

List of figures

List of tables

Chapter 1

Introduction

1.1 Global wine production

Wine is made from the fermented juice of grapes from the species *Vitis vinifera*, which flourishes in warm temperate climates. The historical centre of wine production was Europe and to this day most production takes place in Europe (Table 1).

Table 1 Wine production worldwide in 2006 (Wikipedia, 2005)

Rank	Country	Annual production (tonne)
1.	France	5,329,000
2.	Italy	5,057,000
3.	Spain	3,934,000
4.	United States of America	2,232,000
5.	Argentina	1,564,000
6.	China	1,300,000
7.	Australia	1,274,000
8.	South Africa	1,157,900
9.	Germany	1,014,700
10.	Chile	788,600

New Zealand is not among the world's top 10 wine-producing countries. It is ranked 23rd, producing only 102,000 tonne of wine (102 million L) in 2006 (Anonymous, 2006) but markedly up from 57,000 tonne in 1996. For a number of reasons there is an international glut of wine (Berger, 1999). In the absence of subsidies to maintain profits – as is the case in New Zealand – the only way for minor producers to survive is through a focus on high quality.

Of the two major organoleptic properties of wine, colour and flavour, the latter is the major determinant of quality. Casual inspection of information on the back labels of wine bottles makes this very clear.

1.2 Flavour of wine

The flavour of wine derives from fruit flavours like esters and organic acids, alcohol, residual sugars, and well as a range of phenolic compounds. Of these, tannins derive from seeds and grape berry skins as well. Unquestionably the main flavour of wine derives from the fruit, because wines are nearly always sold according to grape variety. The organization of wine on retail display makes this very clear. Historically, unusual flavours were often added to the wine. The Romans liked to mix honey with this drink to make an aperitif called mulsum (Anonymous, n.d.-b). They also often added herbs and spices, and were known to mix wine with salt water (Anonymous, n.d.-c). Even calcium carbonate was sometimes mixed with wine to reduce acidity. From the Middle Ages on, people were remarkably known put lead acetate (called sugar of lead) into wine and other foods to make them sweeter (Anonymous, n.d.-d)

However, the major non-grape source of flavour in wine is oak, and has been for about 2000 years. When wine contacts (oak) wood, compounds are extracted from the wood into wine, and probably from wine into wood, some volatile compounds particularly ethanol are lost to the atmosphere after diffusing through the wood, and some oxygen from the atmosphere enters the wine after diffusing in the opposite direction.

The wine (and spirit) ageing process in oak wood casks has long been one of the most enigmatic phenomena in the world of oenology. Long experience simply shows that wines and spirits aged in oak casks promote colour and pleasant flavours, leading, in short, to an improvement of quality in these drinks (Martinez, 2001).

As is discussed in more detail later, heating of oak wood at around 200°C results in the controlled pyrolysis of lignin. This generates a range of phenolic compounds that are responsible to a great extent for the organoleptic characteristics of toasted oak. These compounds are present only in traces or they do not appear at all in non-toasted wood (Martinez, 2001). The profile of compounds generated depends on the duration and time of the heat treatment.

1.3 Oak barrels

In ancient times in Europe, wine was stored in ceramic vessels called amphoras, which were sealed with plugs of pine resin. (Resin flavour from Mediterranean pines is a feature of *retsina*, a classic Greek style, but one that has only a national following (Wikipedia, 2006b). The Romans began to use barrels 1800 years BP, as a result of their commercial and military contacts with the Gauls, who had been making barrels for several centuries (Wikipedia, 2006a).

Oak is the thus traditionally and commonly used wood for the creation of barrels in which wine is often fermented and frequently stored in. Barrels were made from oak for a number of reasons. Oak was plentiful in Europe, the region where wine production developed, it bent easily when heated, and produced barrels that did not leak. Moreover, the low resin or innocuous resin contents of oak means those only products of lignin, and to lesser extent (hemicellulose/cellulose), contributed to the final flavour.

The term ‘good quality’ oak is used in wine literature to describe the best wood for barrel construction, but it is not clear whether that means the wood produces a barrel that does not leak (fine grained) or it yields favourable flavours in wine or both. The main sources of oak for barrel making are Europe, mainly France, and the U.S.A. (Pisan, n.d.)

Table 2 Approximate composition of European and American oaks (Anonymous, 1995)

Species	Percent composition of dry weight[a]				
	Cellulose	Hemicellulose	Lignin	Extractives	Ash
European					
European oak	38	29	25	4.4	0.3
Quercus robur[b]	39-42	19-26	25-34	3.8-6.1	0.3
French oak[c]	22-50	17-30	17-30	2-10	Not given
American					
Q. alba[d]	44	24	24	5.4	1
Q.alba[e]	42	28	25	5.3	0.2
Q. prinus	41	30	22	6.6	0.4
Q. stellata	38	30	26	5.8	0.5

a. Values to do not add to 100 because of other components like tannins
b. *Q. robur* is the English oak or Limousin oak, widespread throughout Europe
c. Species not given, believed to be *Q. petraea*, the sessile oak
d. American white oak from swampy land in Georgia
e. American white oak from dry uplands in Tennesseeb.

Other woods have occasionally been used to make barrels, for example, California redwood (*Sequioa sempervirens*). It is no longer used, because it is too rigid to allow bending of the staves and it imparts a yellow tint to the wine (Ross, n.d.). (Moreover, it is not grown as a tree crop and conservation issues would probably preclude contemporary use.)

Chestnut, although high in tannin, is too porous and must be coated with wax to prevent excessive wine loss through evaporation (Ross, n.d.). A wax lining would mean that the wine would not contact the wood, so it would function as nothing more than a containment wall.

Oak, on the other hand, due to its strength, workability and lack of undesirable flavour or colour extractives, is used almost exclusively in the barrel aging of wines. Oak has a relatively tight grain which permits a more gradual extraction of wood flavours and minimizes wine loss through evaporation. It is resilient, enabling staves to be bent without breaking and unlike other hardwoods such as apple or cherry, has a neutral wood smell (Ross, n.d.).

The contact point of wine with wood is obviously on the inside of the barrel. For this reason barrels are toasted literally by setting a fire in the barrel when it is still open at both ends. The heat serves two purposes. First, the barrel staves become plastic as the lignin begins to flow. This allows the staves to be bent into the required shape. Second, pyrolysis develops the phenolic compounds that are eventually extracted into wine (Domine, 2004).

Inspection of wine bottle labels, particularly of red wines, shows an emphasis on claims about exposure to oak barrels in fermentation and/or in wine maturation. Claims include the origin on the barrels, French oak or American oak, their newness and their size. These factors are discussed below.

When new barrels are used at any point of the wine making process, the desirable phenolics from pyrolysed lignin are maximally leached into the wine. Repeated use of the barrels results in progressively lower extraction. Thus claims about, for example, the use of ‘all new French barriques (barrels)’ is important in promotion of wine.

Claims are often made about the size of barriques, particularly in maturation. Small barrels are considered better as is clear from labels. There is obviously a greater contact area with wood per litre of wine, and the desirable minor oxygenation (see later, Section 1.7) can proceed more rapidly (McCord, n.d.). Finally, the used of small oak barrels evokes an image of boutique production and exclusivity.

Purists claim that only barrel contact – either in fermentation, maturation or both – is able to create the classic flavour so loved by connoisseurs. Certainly barrels in a cellar evoke a romance that stainless steel tanks for fermentation and maturation cannot hope to achieve.

1.4 The composition of woods and of oak in particular

Wood is comprised mainly of cellulose, hemicellulose and lignin which are three insoluble polymers with complex structures. In addition there are other classes of compounds with smaller molecular weights such as tannins, resins, and lactones (P. Arapitsas, Antonopoulos, Stefanou, & Dourtoglou, 2004). Cellulose is the most abundant natural polymer on earth's dry land. It is a long chain polysaccharide consisting of glucose units joined by way of β-1,4 glycosidic linkages. It is water insoluble, non-digestible by humans and makes up approximately 40 to 45 % of wood dry weight. Cellulose, in conjunction with hemicellulose, is the woody construction in plants and the main cell wall component. The cellulose gives rise to the high tensile strength because of its crystalline structure and its association with hemicellulose and lignin.

Hemicellulose is a smaller and less stable molecule than cellulose. It is two-dimensional and made up of mainly five- and six-carbon sugars including glucose, xylose, mannose, rhammnose, arabinose and galactose. Hemicellulose contributes to about 25 to 35 % of wood dry weight (Margalit, 2004).

The third main component in wood is lignin. Lignin is the botanical equivalent to concrete used to support the 'steel reinforcing rod' that is the cellulose assembled into wood fibres. Lignin comprises between 20 and 30 % of the dry wood weight. It comprises large, complex, three-dimensionally branched phenylpropanoid polymers (Jackson, 2000). Comparatively little is known about lignin except that it is extremely hard to break down, requiring a lot of mechanical energy and enzyme action to fully degrade. The structure of lignin is different in different woods.

Tannins is another component class present in wood, These are polyphenols. As with lignin, comparatively little is known about these tannins due to their complexity.

From macroscopic perspective, oak is a chemically uncomplicated wood, unlike many tree species such as conifers and rubber-family trees that have resin canals, containing compounds that might, and in certain cases do, impact on wine flavour (Anonymous, 1995). As with all woods, the major constituents of oak are cellulose, hemicellulose and lignin, plus tannins and small quantities of lipids (oils, fats and waxes) (Table 2). The term 'extractives' (Table 2) refers to resins and other matter that is soluble in organic solvents like dichloromethane, and ash in mineral salts.

1.5 The source of wine flavouring in oak

1.5.1 Cellulose

A role for cellulose role in wine maturation and aging has not been shown beyond a role in bacterial action in wine maturation, because heat-generated pairs of glucose units, called cellobiose, can diffuse into wine and act as a nutrient in *Brettanomyces* yeast activity (Renouf & Lonvaud-Funel, 2007).

1.5.2 Hemicellulose

Thermal breakdown of hemicellulose yields a range of compounds including furfural, hydroxymethyl furfural, maltol, cyclotene and sugar condensation products (Figure 1). With the exception of furfural these compounds have sweet-associated burnt-sugar or caramelised aromas and flavours. Acetic acid and very small amounts of methyl alcohol are also formed. Thus the breakdown of hemicellulose yields compounds that add toasty caramel-like flavours, and sometimes colour to the matured wine. In addition there are numerous other compounds released during toasting which have similar characteristics (Hedges, Cowie, Ertel, James Barbour, & Hatcher, 1985).

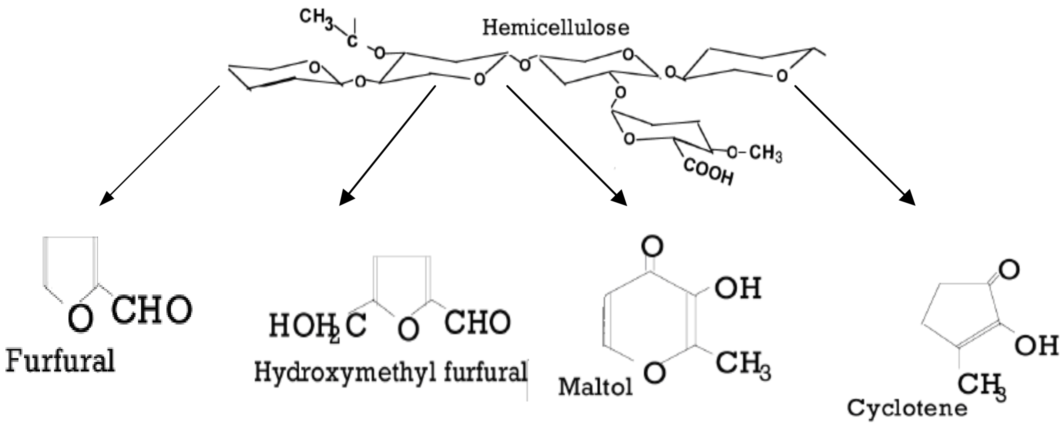

Figure 1 Production of some toasty flavours by breakdown of oak hemicellulose (Anonymous, 1995)

1.5.3 Lignin and the effect of heat treatment

Lignin is not one compound. All lignins are complex, amorphous, three-dimensional polymers that have in common a basic phenylpropane structure. In their natural unprocessed form lignins are complex to the point that none has ever been completely described. They have molecular weights that may reach 15,000 Da or more (McCrady, 1991).

Oak lignin is mainly based on two building blocks, the guaiacyl and syringyl structures. In pyrolysed oak these two building blocks give rise to two groups of compounds – coniferaldehyde, vanillin and vanillic acid in one group from the guaiacyl structure, and sinapaldehyde, syringaldehyde and syringic acid from the syringyl structure.

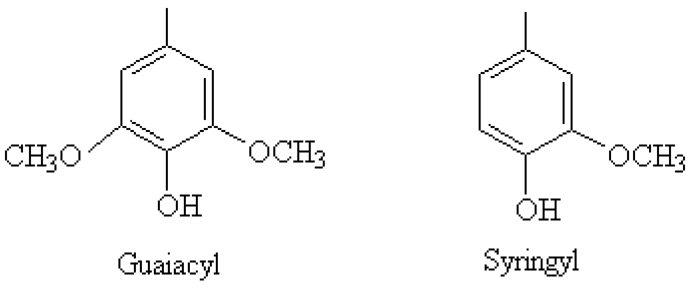

Figure 2 The guaiacyl and syringyl building blocks of oak wood lignin (Anonymous, 1995)

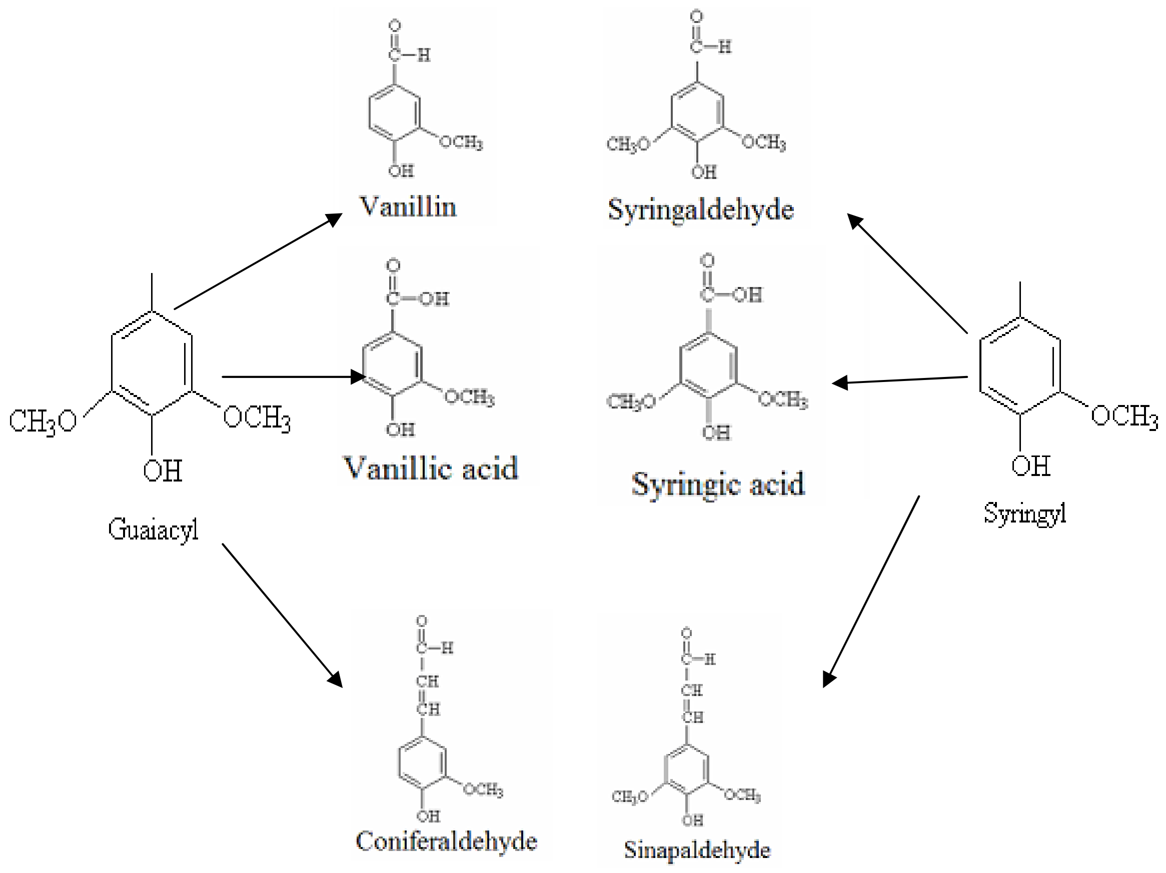

Figure 3 Phenolic aldehydes released from oak wood on maturation (Margalit, 2004)

Toasting of barrels helps to create different flavours to the wine stored in them. The choice of a barrel is very important relative to size, source, degree of toasting, and the cooper's barrel making technique. The degree of 'toasting' of the barrel is either light, medium or heavy. Each degree exhibits quite different aromatic profiles.

The staves are heated, traditionally with an open fire, and when pliable are bent into the shape of the desired barrel and held together with iron rings. Instead of fire, a cooper may use steam to heat up the staves but this tends to impart less 'toastiness' and complexity to the resulting wine (Gayon, 2000). Winemakers can order barrels with the wood on the inside of the barrel having been lightly charred or "toasted" with fire, medium toasted, or heavily toasted. Typically the 'lighter' the toasting the more oak flavour and tannins that are imparted in it. Heavy toast or 'charred' which is typical treatment of barrels in Burgundy wine have an added dimension from the char that medium or light toasted barrels do not impart. Heavy toasting dramatically reduces the coconut note lactones, even in American oak, but creates a high carbon content that may reduce the colouring of some wines. During the process of toasting, the furanic aldehydes in the wood reach higher concentrations. This produces the ‘roasted’ aroma in the wine. The toasting also enhances the presences of vanillin and the phenol eugenol which creates smokey and spicy notes that in some wines are similar to the aromatics of oil of cloves (Gayon, 2000).

These pyrolysis compounds are collectively known as phenolic aldehydes with vanillin being the best known due to its flavour impact. On further heat treatment, the lignin complex can break down into much simpler structures – the volatile phenols which are responsible for the smoky aroma and flavours often found after barrel maturation when the inside of the barrel is charred (Guchu, Diaz-Maroto, Perez-Coello, Gonzalez-Vinas, & Ibanez, 2006).

1.5.4 Tannins

Oak tannins are described as hydrolysable because they can be broken down into simpler structure in acid conditions, unlike grape tannins which are condensed and are less destructible. In oak these compounds are termed ellagitannins, which are phenolic glycosides, and are both astringent and bitter and are very unpleasant. Seasoning (exposure to the weather) and toasting to breaks down the tannins and makes them more flavour acceptable. Tannins also play a role in maturation by taking part in oxidation reactions (Bianco & Savolainen, 1997).

In the presence of a transition metal, e.g., iron, copper or manganese, tannin reacts with residual oxygen in wine generating brown tannin oxidation products and hydrogen peroxide, which then oxidises some alcohol to acetaldehyde. Alcohol subsequently combines with the acetaldehyde to generate a new compound in the wine, diethyl acetal, often just called acetal. In controlled concentrations this volatile is desirable in wine, unlike in beer for example (Bianco & Savolainen, 1997).

1.5.5 Lactones

The oak lactones possess a strong woody character and contribute to the unique aroma and flavour of whiskies. Although they occur in all oak woods used for cooperage, the *cis* isomer occurs in much higher levels in American white oak compared to other species. The *cis* isomer has a stronger flavour character than the *trans* isomer. Both these compounds are derived from small amounts of lipids in the oak and increase in concentration during seasoning and toasting. They can also decrease during toasting (P. Arapitsas, Antonopoulos, A., Stefanou, E., & Dourtoglou, V. G., 2004).

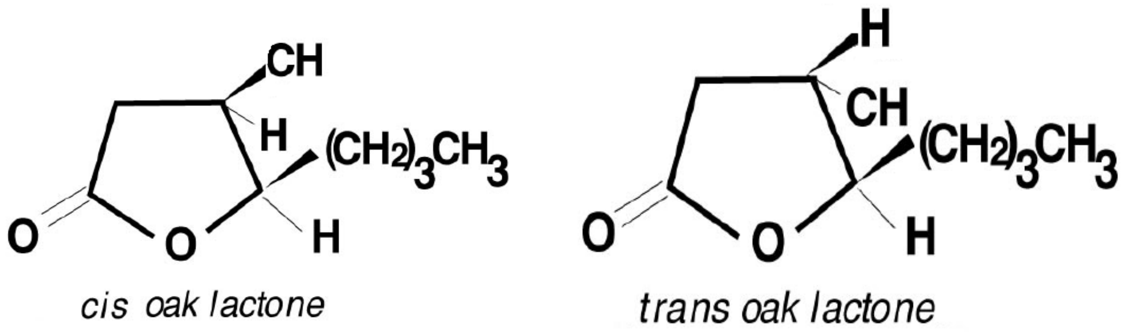

Figure 4 The oak lactones (Anonymous, 1995)

Both isomers are described as woody and coconut-like with the *cis* isomer being much stronger. The *cis*- isomer is also being reported as rose-like and *trans* isomer celery-like (P. Arapitsas, Antonopoulos, A., Stefanou, E., & Dourtoglou, V. G., 2004).

1.6 Alternatives to oak barrels

In 2002, the barrels made of French oak cost almost US$600 whereas barrels made of American oak cost about half of that. A barrel of wine holds approximately 300 bottles of wine, so the additional cost of oak barrels is between $1 and $2 per bottle of wine assuming a barrel is used only once. Additionally, the maintenance of oak barrels costs about $50 to $60 a year per barrel (Manuel, 2002).

The obvious alternative to the use of barrels is to toast oak pieces and add these to wine. This amounts to putting wood into wine rather than wine into wood. This is done commercially throughout the world. Wineries have experimented with chips and blocks, staves, oak powder, oak cubes, planks (Lindroos, 2005). According to this author, oak chips and blocks are the most popular barrel alternative with wineries of all sizes. Toasted staves-lengths of oak are the next most popular alternative (Manuel, 2002).

Alternatives to oak barrels were first used because of cost. Oak powder, chips, cubes, staves and planks are cheap compared with barrels (Wikipedia, 2006b). According to

(Manuel, 2002), the cost of oak flavouring per bottles is about $2 for French barrel oak, $1 for American barrel oak, 3 to 8 cents for cubes, and approximately 1 cent for wood chips.

New Zealand is well placed to use oak pieces to flavour wine. There are no appellation rules preventing it and much production is done in stainless steel tanks, from a heritage derived from the dairy industry. Stainless steel tanks are durable, and are easy to clean and sterilise, and can be reused (Mueller, 2004). However, stainless steel is completely gas impermeable, and the low exposure to oxygen experienced by wine in oak barrels does not occur in stainless steel. This low exposure to oxygen contributes to wine ageing over the period of barrel maturation (Manuel, 2002). Thus, the use of oak pieces in place of barrels may not yield the sought-after complexity of flavour in higher prices wines. This limitation has now been overcome by micro-oxygenation.

Micro-oxygenation is the continuous addition of small and controlled amounts of oxygen to wine during maturation (Anonymous, n.d.-e). The process replicates the transmission of oxygen through the wood that occurs naturally when wine is matured in barrels. It is essential to know the concentration of dissolved oxygen in the wine at the outset, and the rate and amount of the addition, for there should be no accumulation of dissolved oxygen in the wine during the process.

Winemakers who do not use barrels are increasingly using micro-oxygenation in their process (Goode, 2005). Thus issues of oxygenation can be overcome, and barrel usage continues to decline. Results from the 2006 Wine Business Monthly Barrel and Oak Survey (USA) (Pregler, 2006) show that wineries overall are decreasing their use of barrels and are increasing their use of alternatives, including micro-oxygenation. The survey indicates that small wineries, in particular, are significantly stepping up their use of barrel alternatives. In addition, mid-size wineries are continuing to increase their adoption of alternatives and, in many respects, are beginning to resemble large wineries, which have been aggressively using oak alternatives for some time.

Another important finding of the 2006 Survey is that wineries' views of alternatives are shifting. Quite simply, wineries now view the use of alternatives-especially when combined with the use of micro-oxygenation as another path to producing quality wine (Pregler, 2006).

1.7 Toasting of oak chips

Exactly as for oak barrel staves, oak chip chemical composition depends on the species, growing conditions and tree age, and the various treatments the wood undergoes in cooperage, such as seasoning and toasting (Yildiz & Gumuskaya, 2007). What is not clear from industry web sites or the scientific literature is whether wood chips destined for commercial toasting have been seasoned or not, in the same way that staves are. Seasoning reduces the concentration of ellagatannins that would otherwise lead to excessive astringent and bitter flavours in wine. Ignoring this question it seems clear that toasting of (uniformly sized) wood chips would parallel that of barrels except with potentially more control. And intuitively, an oven is more controllable than a fire. Chemically the outcomes will be the same on average. Thus, (Frangipane, Santis, & Ceccarelli, 2007) and (Vichi et al., 2006) all report infusion of compounds into wine from toasted chips that also infuse from toasted barrels.

A solid object contains more heat energy per unit volume. Heating activity generally occurs on the surface of the solid particles. Therefore, decreasing particle size, through its effect of increasing surface area, will encourage heating process and increase the rate of heat transmission. On the other hand, when particles are too small and compact, air circulation through the pile is inhibited. This decreases oxygen available within the pile and ultimately decreases the rate of heat passing through the wood chips.

Particle size also affects the availability of carbon and nitrogen. Large wood chips, for example, provide a good bulking agent that helps to ensure aeration through the pile, but they provide less available carbon per mass than they would in the form of wood shavings or sawdust.

The existance of toasted oak powders as a commercially available strongly suggests that infusion of flavour from wood is governed by surface area in the short term.

1.8 Prior research on wood chips in wine from other species

The idea that other wood species could be used in chip form to flavour wine has curiously, never been posed or certainly addressed in the scientific literature. Preliminary experiments by an undergraduate student at AUT (Burns, 2005) have shown that other wood from species like kahikatea, manuka, pohutukawa and totara generate different and potentially useful flavours.

These four New Zealand native woods were used for flavouring wine plus American oak. These woods as chips were then submitted to a toasting process for a period of two hours in a domestic oven, relying on the manufacturer's temperature calibration at 200°C.

After toasting the chips were added to an unoaked chardonnay in a set mass to volume ratio and left to infuse for two weeks at room temperature. Sensory analysis was subsequently done on these wood-treated wines along with an unwooded control, making six treatments in all.

Hedonic assessment by comments alone was performed blind by 33 wine drinkers passing on a Saturday through a retail wine shop catering for the wine enthusiast. Most of the descriptions were for oak-associated attributes and a range of oak-related words were used multiple times. Kahikatea appeared to yield a very smoky/bacon note mixed with nutty, savoury attributes and a little less of the summer fruit note compared to that of totara. Totara had high fruit/floral, creamy and sweet notes. Both were described as being buttery, as these terms were used in multiple occasions. Manuka was most often described as oak-like, and with the greatest similarity of other flavours. Pohutukawa elicited the fewest responses.

All the treatments had responses ranging from no oak present – particularly the control – through to a full oak presence.

1.9 Aim of the study

This study extends the work of (Burns, 2005) to the qualitative and quantitative organoleptic attributes of wine flavoured with chips from many woods indigenous to or strongly associated with New Zealand. The wine of choice was an unoaked chardonnay, the white wine most often subjected to oak exposure during fermentation and/or maturation.

The data gathered were as follows: dimensions of the wood chips, weight loss of due to drying and to toasting to two temperatures/times, colour arising from toasting, qualitative descriptive analysis of wines infused with 24 species x toasting treatments, and an hedonic analysis for six of those treatments.

The overall aim of this research was to find woods and treatments that could be used to create unique 'New Zealand character' wines.

Chapter 2

Materials and methods

2.1 The experimental plan

The outline of the experimental approach is shown in Table 3. There are three main areas of work leading an overall discussion and conclusion. Wood preparation was a major part of the study because the woods have to be to cut into chips of defined dimensions for reasons discussed later. Infusion was quick and easy. The sensory assessments were in two parts, one a wide ranging largely qualitative assessments of woods and toasting, subsequently narrowing to a six-treatment hedonic trial in wine shops.

Table 3 Outline the experimental approach in chronological order

Event	Analysis	Reported in Chapter
Selection of woods		2
Chip preparation	Dimensions	2, 3
Drying and toasting	Weight loss, colour	2, 3
Infusion of wood into wine	Inspection	2, 3
Qualitative/semi-quantitative assessment of wine flavour	Sensory evaluation	2, 4
Hedonic assessment of wine flavour	Sensory evaluation	2, 4
Discussion and conclusion		5

2.2 Woods

2.2.1 The plan and choice of woods

It is known that the organoleptic characteristics of wines aged in wood are profoundly influenced by the geographical origin of wood used. The ever-growing need for wood barrels, and the consequent increase of costs due to the limited availability of materials, has led some producers, especially those in the emergent countries, to use wood-shaving chips instead of oak wood (Frangipane et al., 2007).

The woods used in this research (Table 4) were chosen on several criteria. With a view to geographical distinctiveness or exclusivity in wine at retail, numbers of native New Zealand woods were chosen. On the basis that oak is a low resin wood that is also used in smoking foods, a native wood commonly used in smoking – manuka – was also chosen. Two of its relatives were similarly chosen. Finally, exotic woods that have become part of the New Zealand ethos were also chosen. Apart from the choice of low resin woods, there was no expectation of suitability of any of these woods for use with wine.

Table 4 Woods chosen for this research

Common name	Botanical name	Nativity	Source	Supplier
Matai	*Prumnopitys taxifolia*	Native	Unknown	South Pacific Timber[1]
Feijoa	*Feijoa sellowia*	Exotic	Hamilton	Dr Owen Young
Macrocarpa	*Cupressus macrocarpa*	Exotic	Unknown	South Pacific Timber
Pohutukawa	*Metrosideos excelsa*	Native	Maraetai	Mr Bernie Cook
Radiata pine	*Pinus radiata*	Exotic	Unknown	South Pacific Timber
Totara	*Podocarpus totara*	Native	Unknown	South Pacific Timber
Kahikatea	*Dacrycarpus dacrydioides*	Native	Unknown	South Pacific Timber
Rimu	*Dacrydium cupressinum*	Native	Unknown	South Pacific Timber
Cherry beech	*Nothofagus solandri*	Native	Unknown	Rosenfeld Kidman[2]
Silver beech	*Nothofagus menziesii*	Native	Unknown	Rosenfeld Kidman
Manuka	*Leptospermum scoparium*	Native	Waikato	Dr Owen Young
American oak	*Quercus alba*	Exotic	Unknown	Rosenfeld Kidman

[1]South Pacific Timber, Ruru St., Eden Terrace, Auckland
[2]Rosenfeld Kidman, Penrose, Auckland

Matai is a New Zealand native podocarp found throughout New Zealand and is particularly abundant in the central North Island. Matai wood is both hard and tough and was commonly used as a flooring wood. The wood has an aromatic smell implying significant resin content.

Feijoa is a native of south-eastern Brazil and Uruguay where it grows naturally in subtropical to warm climates. Feijoa was introduced into New Zealand in 1908 (Anonymous, 2005) and now is found throughout warmer parts of New Zealand. Feijoa is a relative of the New Zealand native pohutukawa (*Metrosideros excelsa*, Myrtaceae), and was chosen because the latter is sometimes used as a smoking wood.

Cupressus macrocarpa is the native American Monterey cypress, commonly known as macrocarpa in New Zealand, where it is a common botanical feature throughout the country, particularly on farms. It is a distinctly aromatic wood that is used in rough farm construction, used as ground-durable posts, and is also used as a furniture wood.

Pohutukawa is a native New Zealand tree that occurs in the coastal regions of the North Island of New Zealand. Pohutukawa is a cultural icon, a fact that could be capitalised on in the marketing of a unique wine, although it is currently a protected species. Amateur fishers use this wood for fish smoking, implying low resin content.

Like *Cupressus macrocarpa*, *Pinus radiata* is a native of Monterey, California. It is well adapted to the soils and climatic conditions of New Zealand and was chosen because it is the major construction wood in New Zealand.

Totara is a New Zealand native tree and was once readily available. Totara is very durable wood in ground contact, and so was used as a fencing material. It is now a protected species, but commercial lots of what is claimed to be recycled totara are available for sale by internet auction (Trademe, 2007).

Kahikatea is a New Zealand native tree. It had an historic use as a box timer for butter crates prior to the advent of cardboard packaging. It is non-odorous, which was presumably the reason that it was used for this purpose. It has presumably low resin content.

Rimu is an also a New Zealand native tree, and has a history as a construction wood, a furniture and decorative flooring wood, and as a firewood.

Forests were dominated by beech (*Nothofagus*) species cover about 2.9 million hectare and account for almost half of the total area of indigenous forest in New Zealand (Davis, 2004). Therefore, silver beech and cherry beech were used for this project. The genus *Nothofagus* is a relative of oak (Langdon, 1947).

Manuka is an abundant New Zealand native shrub. With its irregular growth habit it is completely useless as a source of sawn wood, but is a favoured firewood because of its longevity and heat output. It is without doubt the most popular wood for amateur and commercial food smoking, and has achieved iconic status for this purpose (Anonymous, 2004). It is presumably low in resin.

The American oak is a traditional wood used for barrel construction and ageing of wine and other alcoholic drinks. It was used as the reference wood in the current research.

2.2.2 Preparation of the wood

The scale of the experimental treatments did not exceed 2.3 L (see later), and the nominal exposure rate of wood to wine was 5 g L^{-1}. Thus the 2.3 L treatments would contain no more than 12 g of toasted wood. Wood cut in a conventional wood chipper could generate single, and highly variable chips, that could exceed that mass. Use of chips of that size would introduce unacceptable variability, assuming that infusion of flavour compounds was likely to be governed by surface area not mass. This is almost certainly true for a number of reasons. Winemakers favour small barrels for maturation implying a surface area to volume effect, barrels do not leak even over many years suggesting that infusion is governed by surface area, and barrels are reconditioned by shaving the interior surface to expose a fresh surface. Thus, the only way that controlled and equal exposure could be obtained on a 2.3 L scale was to machine wood into small, uniformly-sized chips to generate a constant surface area.

The woods (Table 4) were first cut longitudinally with the domestic band saw into nominally 10 mm sheets. These were then cut longitudinally into strips, which were finally cut across the grain in 20 mm lengths with a domestic mitre saw fitted with a fine cutting blade. This was facilitated by binding bundles of strips with adhesive paper tape loops at about 100 mm intervals along the bundle. These were progressively removed as the cutting advanced through the bundle.

2.2.3 Drying and toasting

The amount of oak compounds extracted by wine depends on contact time, temperature and initial concentration in wood, which in turn depends on the type of wood, employed and can be notably increased by subjecting the wood to a toasting process. During toasting, large wood polymers such as lignin or cellulose are fragmented by high temperature and many compounds such as phenols, aldehydes, furfural derivatives, lactones, etc. are formed (Bozalongo, Carrillo, Torroba, & Tena, 2007).

The moisture content of the untoasted wood chips, but excluding macrocarpa and feijoa, was measured. The amount of available macrocarpa and feijoa was not enough for moisture content determination. The AOCS official method Aa 3-38 was adapted to determine moisture content. To measure the moisture content of the wood samples, was used. For each wood, about 25 g of accurately weighed untoasted wood chips was placed in a weighed glass dish and placed in a conventional laboratory at 110ºC for five hours. After cooling in a desiccator the dishes were reweighed. The moisture content percent was calculated as follows.

$$\text{Moisture content (\%)} = \frac{\text{Loss in mass (g)}}{\text{Original sample mass (g)}} \times 100$$

In parallel with moisture determinations the wood chips were heat treated, called toasting in the context of wood and wine. Two levels of toasting were selected, light toasting (200°C for 2 hours) and heavy (210°C for 3 hours). These temperature and times were chosen after empirical trials. Two hundred grams of chips of each wood were toasted. The oven was a Sanyo laboratory oven Model MOV- 112F (Sanyo, Japan), which included an air circulation fan. For toasting, the chips were placed in lipped aluminium baking trays, which were loosely covered with aluminium foil to minimise air exposure, and thus discourage combustion.

Oak toasting increases the amounts of compounds deriving from thermal degradation of lignin (vanillin, eugenol, guaiacol and its derivatives) and the pyrolysis of cellulose and hemicellulose (furfural and 5-methylfurfural) and decreases the concentration of the two whisky lactone isomers (Bozalongo et al., 2007).

2.2.4 Dimension of the wood chips

The size of the wood chips used for the sensory evaluation may influence the extraction of the compounds from the wood into wine (see earlier in section 2.2.2), and potentially from the wine into wood. Twenty wood chips for the untoasted woods were randomly picked for each wood type, and the thickness of the narrowest dimension was measured in millimetres with the vernier callipers.

2.2.5 Colour measurements

The colour of the untreated and toasted wood chips was measured in Hunter colour space (Figure 5). The principle of the Hunter colour system is based on the concept of a colour space with the colour defined by three coordinates, L*, a*, and b* values (Coultate, 2002). The vertical coordinate L* is lightness from 0 (total light absorbance and therefore completely black) through grey (50) to 100 (complete light reflectance); the horizontal coordinate a* is greenness/redness, from – 60 (green) through grey to + 60 (red); an orthogonal horizontal coordinate b* is yellowness from – 60 (blue) to + 60 (yellow). It is shown in Figure 6.

Hue angle refers to the gradation of colour within the visible spectrum of light. Hue angle is arctangent (b*/a*) determined by rotation about the a* and b* axes.

Chroma or saturation is the intensity of a specific hue: a highly saturated hue has a bright, intense colour, while a less saturated hue appears gentler. Chroma is defined as $\sqrt{(a^2+b^2)}$. Thus L* (lightness), hue angle and chroma are values that theoretically describe all perceived light.

A Hunter colorimeter (ColorFlex, Hunter Associates, Virginia, USA) was used to measure the colour of wood chips. A Duran cylindrical glass dish (Schott, Germany) measuring 2.5-inch was diameter placed in the illuminant path of the instrument and was totally covered with a black shroud. A daylight (D65/10°) illuminant/observer combination was selected to record L*, a* and b* values.

The glass dishes were filled to 10 g in order that no light would pass through the gaps of the wood chips. The readings were then taken using the Hunter colorimeter.

Figure 5 A Hunter colorimeter (ColorFlex, Hunter Associates, Virginia, USA)

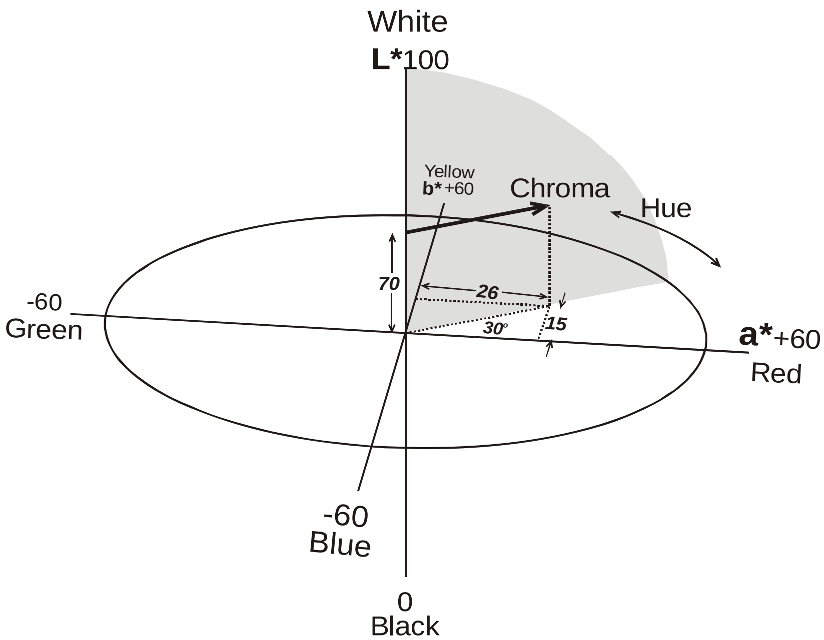

Figure 6 In L* a* b* colour space, the tip of the thick arrow is defined by its lightness (70 on a scale of 0 to 100), its redness (+26 on a scale of –60 to +60) and yellowness (+15). The hue is arctangent 15/26 (= 30°) and the chroma, or intensity, is the length of the thick line, √(152 + 262) (= 30) (Young & West, 2001)

2.3 Wine

2.3.1 Source

About 100 L of 2004 chardonnay from Gisborne, New Zealand, was donated for this research by Mr Simon Nunns of Coopers Creek Vineyard Limited. The wine had pH of 3.44, total acidity of 6.8 $g.L^{-1}$, residual sugar of 4.0 $g.L^{-1}$ and an alcohol content of 13 % (v/v) as determined by the winery. It was supplied in sealed 20 L plastic containers, to which had been added an undefined quantity of metabisulphite. The wine was later transferred to 2.5 L dark brown glass bottles that were filled to the top to minimise air exposure, and immediately sealed with plastic screw caps. These bottles were progressively used for experiments.

2.3.2 Infusion

The toasted wood chips were placed into the bottom of blue-capped 1 L Schott bottles. The chips were added to the wine at a standard ratio of 5 $g.L^{-1}$, but initially only 30 ml wine was added. An inverted rubber bung with a coaxial 6 mm plastic tube fully covered the mouth of the Schott bottle. The tube was connected to the diffusion vacuum pump. A vacuum was then created to remove air – or more importantly oxygen from the wood chips. The vacuum was applied for typically five minutes, by which time the rate of bubbling due to dissolved gas was much reduced. The bottles were then completely filled and capped. They were stored for two weeks in a dark place at ambient temperature. Control wine was similarly treated but no chips were used.

The procedure followed for infusion of the wood chips into the wine was: 1g of the small oak chips and 8 g of the big oak chips were added to 200 ml of wine sample in order to have about the same surface of contact in both cases. The wine samples were then stored in closed flasks for 1, 2, 3, 4, 5, 6, 7 or 14 days (P. Arapitsas et al., 2004). There were two infusion sessions. The first was to generate 25 treatments for qualitative/semi-quantitative analysis by people self-declared as discerning wine drinkers or acknowledged as discerning by involvement in the wine industry. There were 12 light and 12 heavy toasting treatments plus one no-wood control. The second was to generate 6 treatments for quantitative analysis by people self-declared as discerning wine drinkers. There were 6 wines chosen from the above 25 treatments. There were 36 bottles in all. Six bottles per wine shop were chosen.

2.3.3 Filtration

After two the standard two week storage period the wines were individually filtered through glass-wool, directly into tall form dark-green wine bottles with conventional Stelvin screw caps. The bottles were completely filled and sealed to keep out air. The bottles were placed in cartons to avoid light exposure and to air handling.

2.4 Sensory analysis

The choice of sensory analysis method was governed by the complete novelty of most of the treatments. Because the flavour outcomes of the infusions could not be predicted it was decided to first explore the flavour by descriptive response as described below. It was hoped that that research would identify woods with the potential to flavour wine in distinctive and attractive ways. In the event this hope was realised and the second assessment was hedonic in a commercial environment.

The first assessment was a qualitative/semi-quantitative trial by people self-declared as discerning wine drinkers or acknowledged as discerning by involvement in the wine industry. There were two sites for this trial, Fine Wine Delivery Company, Cook Street, Auckland, using nine staff members who were experienced wine tasters, and at AUT University's Food Science laboratory using 28 staff members. With the possible exception of some of nine tasters at Fine Wine Delivery Company in Auckland, none of the panellists was trained.

There were 12 light and 12 heavy toasting treatments plus one no-wood control involved in the trial. The tasters were provided with the 25 samples in a set order and an A3-format sensory evaluation ballot sheet on which 14 different tastes were described, like 'sweet oak', 'toasty oak', 'smokey', 'vanilla', 'butter-scotch', 'buttery', 'fruity', 'soapy', 'honey', 'savoury', 'yeasty', 'nutty', 'earthy', and 'sappy'. These were chosen from discussion with Mr. Geoff Poole, principal of Fine Wine Delivery Company, and are typical of expressions used by wine connoisseurs. An additional column was provided so that tasters could describe whatever taste they could not find among the designed descriptors.

Figure 7 Arrangement for qualitative/semi-quantitative trials in the laboratory

Figure 8 A lady tasting 25 different treated samples of wooded wines

The room at Fine Wine Delivery was a dedicated tasting room, while the room at AUT was a well-ventilated food science laboratory. Both venues were quiet and odour free. Silence was be maintained during the trials. At both sites the format was the same. For each taster, the samples of wine in 35 ml polypropylene tasting glasses were tasted serially in a constant order. Water was provided for mouth rinsing after every tasting. Smell and taste both were the key points for these assessments. Tasters were asked to fully evaluate the wine in the mouth, but they were not required to swallow. An unknown number of tasters did swallow an unknown number of wines. After completing assessment of the 25 wines, the tasters were required to nominate the three wines they liked most and the three they disliked the most.

The second evaluation was a conventional hedonic trial performed in six retail wine shops in the early evening. These shops were Balmoral Wines and Spirits, Parkland's Liquor Centre, The Village Winery in Mount Eden, The Thirsty Frog Wines and Spirits in Pakuranga, The Wine Vault in Grey Lynn and Greenlane Liquor Centre. A stall was set up near the entrance, and the trial was announced by a poster stating the nature of the trial. The consumers who took part were self-declared wine drinkers. Six wines (to be identified later) were assessed including the non-wood control, requiring a total of 36 bottles. The screw cap bottles were same size, shape and colour, and were filled completely to avoid oxidation within the three weeks required to do the trials. The bottles were on display, each labelled with a plain three-digit random number coding for the wine. These numbers were generated from a series of the last three digits of telephone numbers in a directory.

For each consumer, the samples of wine 35 ml polypropylene tasting glasses were assessed and swallowed or spat at will. Swallowing was much more common. The ballot sheet comprised six vertical columns of boxes headed with the three-digit number. Unlike the tasting trial at Fine Wine Delivery and AUT, the order of presentation followed a pattern designed to ensure that each wine had the same frequency of exposure, and the same chance of following every other wine (pattern supplied by Dr O.A. Young).

The likings and disliking were based on a nine-point hedonic scale, in which consumers had to tick to indicate choice. At each wine shop 30 panelists completed the ballot, making 180 responses in all. The consumers also had to identify their gender, and age in three ranges, 18 to 30 years, 31 to 45, and 46 and older. They were encouraged to make comments, although few did.

2.5 Data analysis

Because each wood was toasted only twice (to 200 and 210°C), weight loss data are presented as single values. Colour data from these single replicates are presented as means and standard deviations from replicate colour determinations.

For the qualitative/semi-quantitative trial there were 25 treatments. After data were marshalled into an Excel spreadsheet, that program was used to compute and plot the selection frequency of the three most liked and most dislike treatments. A Chi-square test (Minitab Release version 14, Minitab, Pennsylvania) was also applied to the frequency data to formally identify outstanding treatments.

Principal component analysis of a correlation matrix (Minitab) was used to summarise panelist responses to 13 descriptors offered in the ballot (Table 5). The PCA plots (Minitab) presented in this thesis are scaled to portray the fraction of information contained in each dimension or principal component.

For the effect of the comments on the three most liked and three most disliked data against total ‘Other’ comments regression analysis was used. Least squares lines of best fit were calculated for these two data sets, using Microsoft Excel.

Wine shop (6), gender (2), and age of panelist (3), were the factors used to analyse the variance of liking of the six wines used for the hedonic trial. This was done with Minitab’s General Linear Model. Tukey’s significant difference test ($P < 0.05$) was used to compare individual wine means.

Chapter 3

Results and discussion of wood preparation and infusion

3.1 Wood chip dimensions

The dimensions of the wood chips were nominally 2 x 10 x 20 mm, where the longest dimension was along the grain. Cutting the narrowest dimension accurately was difficult, resulting a range of thicknesses within and between woods (Table 5). Cherry beech and rimu chips were the thickest, and matai chips the thinnest by a considerable margin. However, it was thought unlikely that the differences between woods would affect the extraction of flavour compounds, because toasting is likely to expose cavities in the chips that would facilitate extraction of toasting products.

Giménez Martínez et al. (2001) heated American oak wood particles of varying sizes (up to 14 mm diameter) at 185°C for three hours and subsequently determined the concentrations of vanillin and syringealdehyde in wine spirit extracts of these particles. For oak particles ranging in size from < 0.1 mm up to 5 mm in diameter, the concentrations of vanillin and syringealdehyde were proportional to the particle size, with more vanillin and syringealdehyde extracted from the 3–5 mm diameter chips (Campbell, 2005). However for chips greater than 5 mm in diameter the opposite effect was observed. It is possible that the very small particles gave a greater evaporative loss of these volatiles in their study, although it is difficult to distinguish decomposition from evaporation in general.

Because the various effects of heating on oak lactones appear to be highly variable, it is not possible to predict all of the outcomes of different heating regimes (Campbell, 2005). This needs to be determined by sensory and chemical analyses of individual sample batches.

Table 5 Mean thickness of the narrowest dimension of untoasted wood chips

Wood	Thickness of wood chips (mm)
Matai	†2.22 ± 0.41
Feijoa	2.73 ± 0.72
Macrocarpa	2.46 ± 0.58
Pohutukawa	2.57 ± 0.84
Radiata pine	2.45 ± 0.51
Totara	2.67 ± 0.73
Kahikatea	2.49 ± 0.36
Rimu	3.10 ± 0.60
Cherry beech	3.17 ± 0.82
Silver beech	2.64 ± 0.52
Manuka	2.40 ± 0.65
American oak	2.70 ± 0.49

† Data are means of 20 chips ± standard deviations

3.2 Toasting

Macrocarpa, kahikatea and rimu caught fire during toasting at 210°C for three hours, generating copious quantities of smoke that also extinguished the flames. In all cases however, the total time and temperature regime was adhered to.

3.3 Weight loss on drying and toasting

The amount of oak compounds extracted by wine depends on contact time, temperature and initial concentration in wood, which in turn depends on the type of wood, employed and can be notably increased by subjecting the wood to a toasting process (Bozalongo et al., 2007).

The dry weights measure (110°C for 5 hours) was done for all the woods except feijoa and macrocarpa because there were not enough chips for three treatments (drying and two toasting levels). Figure 9 shows the weight loss on drying and toasting, where each bar represents a heat treatment from an ambient starting point. That is, the changes are not cumulative.

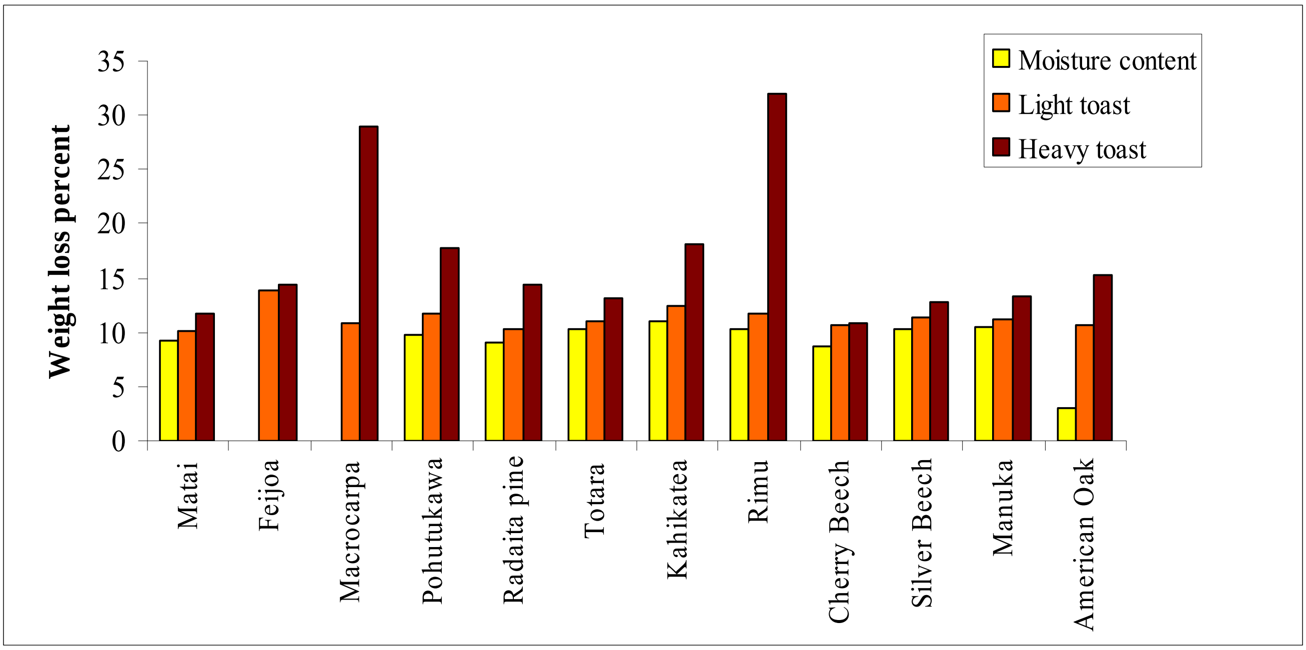

Figure 9 Percent weight loss of woods on drying and toasting

Subsequently, fresh samples of wood chips were heated to 200°C for 2 hours for light toasting and 210°C for three hours for heavy toasting. Figure 9 shows the weight loss percent of the original chips.

Except for American oak at 3.03 %, the moisture contents of all other woods measured were similar, ranging between 8.68 % (cherry beech) and to 11.1 % (kahikatea), with a mean 10.0 %. Weight losses on light toasting were minor except for American oak. This is seen more clearly in Figure 10, where the loss of weight due to moisture has been subtracted from the losses due to toasting. (Note that data are not available for feijoa and macrocarpa.)

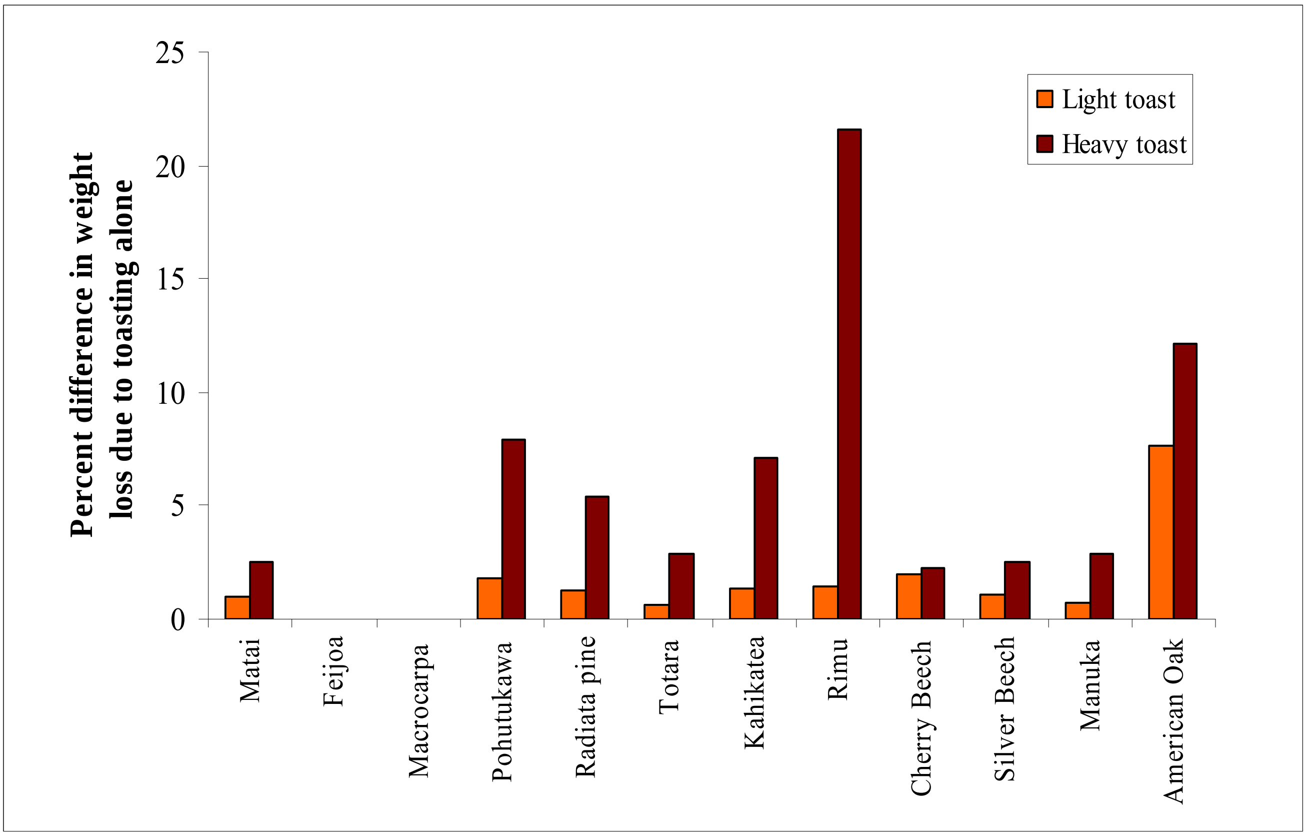

Figure 10 Differences in the weight loss after toasting and subtraction of drying loss at 110°C. (No data were available for feijoa and macrocarpa.)

All the woods lost weight due to pyrolysis and/or further loss of moisture. The mean loss on light toasting after subtraction of moisture content data was 1.90 % ranging between 0.66 (totara) and 7.67 % (American oak).

On heavy toasting the differences between woods in percent weight loss after subtraction of moisture content data were large (Figure 10). The mean loss was 6.72 % ranging between 2.2 % (cherry beech) and 21.6 % (rimu). The moisture-subtracted data for macrocarpa are not available, but it is clear from Figure 9 that weight loss for this species is also high. Rimu and macrocarpa generated copious quantities of smoke during heavy toasting with signs of burning (rimu particularly), thus accounting for the loss. Kahikatea also generated much smoke, but its weight loss on heavy toasting was not particularly severe (7.1 %).

(Di Blasi, Branca, Santoro, & Perez Bermudez, 2001) investigated the influence of the wood variety (five different species) on the dynamics of weight loss of packed wood chip beds exposed to rapid external heat transfer rates. The comparable physical properties of the wood chips allowed the same thermal conditions to be established for all the wood varieties, corresponding to average heating rates.

The distribution of pyrolysis products (chars and volatiles) is highly dependent on the hemicellulose content of wood. In particular, char yields are successively higher as the lignin and/or the extractive contents increase. For a given hemicellulose content, the higher the extractive content the higher the char yield is. The maximum devolatilization rate and the time of its occurrence are also determined by the hemicellulose content. The role of the wood category (hardwoods or softwoods), that is, the different nature and reactivity of the components, is negligible in relation to issues discussed above.

In contrast, the wood category is important for the initial degradation temperature and the duration of the conversion process, that is, the conversion time. These parameters are largely determined by the lignin degradation characteristics. Hence, given the higher degradation temperatures of softwood lignin, more severe thermal conditions for the beginning of the degradation process and longer times of conversion are required for this wood category (Di Blasi et al., 2001).

In general, although the degradation dynamics of the different wood varieties tend to become the same as the reaction conditions are made more severe, from the quantitative point of view, differences still remain great. For the wood varieties examined in his study and severe thermal conditions, the solid residues differ by up to 10% (initial dry mass basis) and conversion times differ by factors of up to 1.5.

3.4 Colorimetric results

The daylight colour parameters, L*, a*, and b* were measured (five replicates) for undried, and the two toasting levels of each wood. a* and b* values were used to calculate hue angle and saturation. The means and standard deviations are summarized in Appendix 1 where the data are normalised to the undried colour values. The data have been later sorted in the descending order with respect to the light toasting in the figures below.

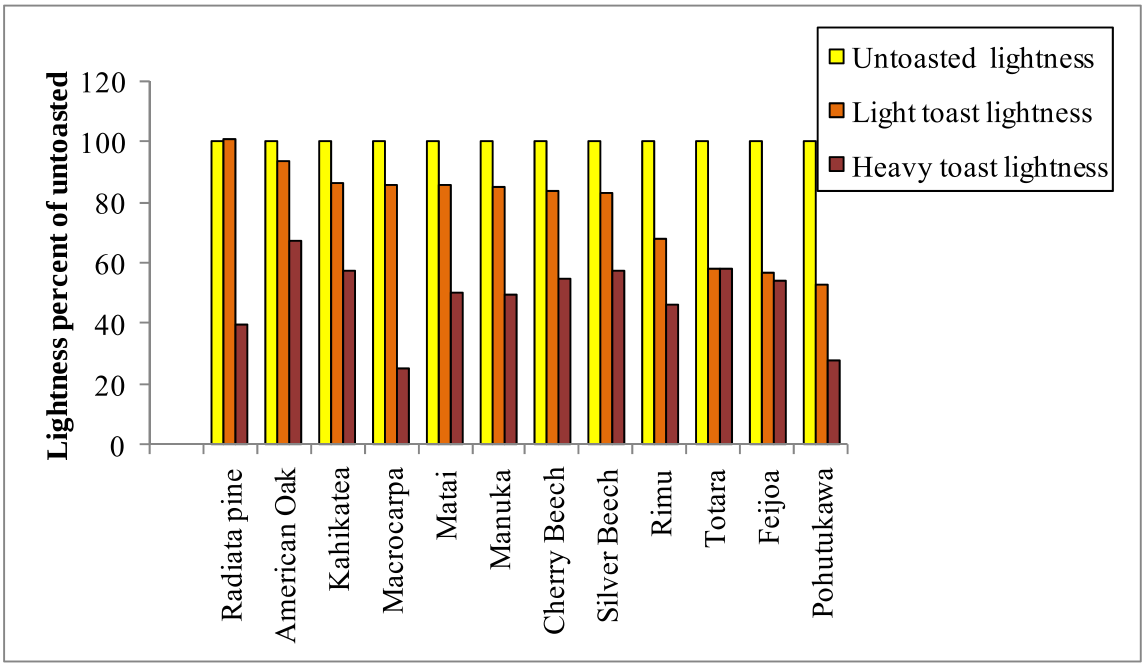

Figure 11 Lightness of woods at different toasting levels relative to untoasted lightness, and in descending order of light toasting values

Lightness, which is a measure of percent light reflected, decreased with light toasting for all woods except radiata pine. For light toasting, the outstanding woods for high loss of reflectance were totara feijoa and pohutukawa . Radiata pine and oak were at the other extreme. On heavy toasting, all woods lost reflectance, particularly macrocarpa, pohutukawa and radiata pine; whereas radiata pine was virtually unaffected by the light toast it was strongly affected by the heavy treatment (Figure 11).

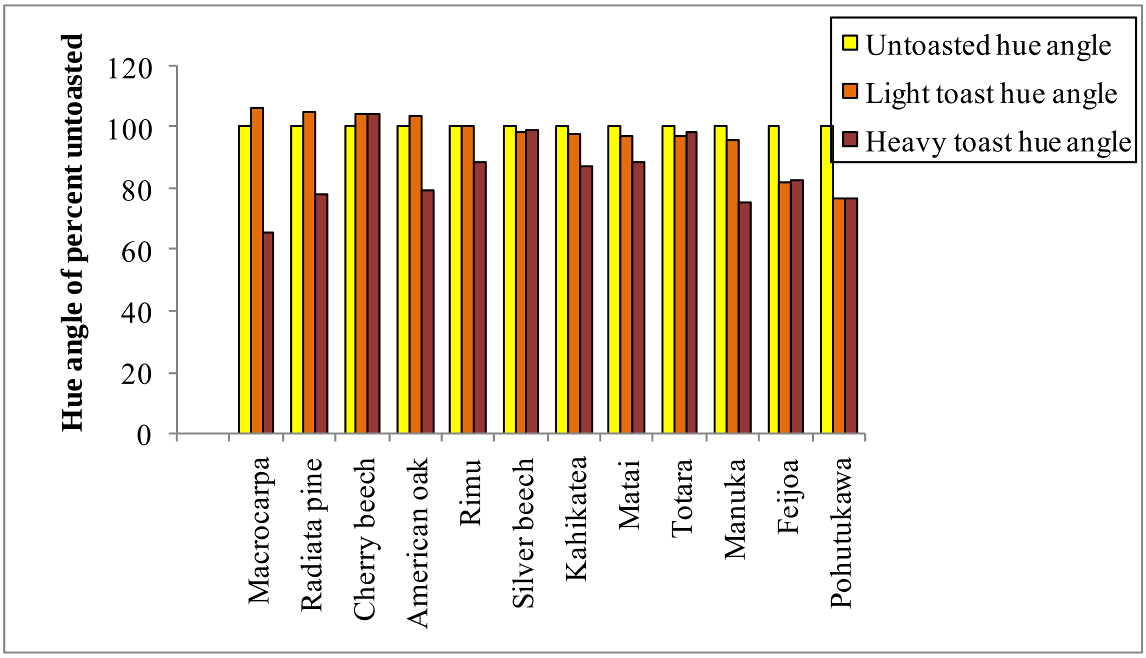

Figure 12 Hue angle of woods at different toasting levels relative to untoasted lightness, and in descending order of light toasting values

Hue is the fundamental colour of an object. With the exception of feijoa and pohutukawa, there was little change in hue angle of the woods due to light toasting. Feijoa and pohutukawa were the same two woods that suffered high loss of reflectance on light toasting. On heavy toasting, totara and the two beeches retained the original hue of the untoasted wood. All other woods suffered a decrease in hue angle, which in the red/yellow quadrant of the hue circle (Figure 6) meant that the colour was becoming less yellow and redder. Macrocarpa had the greatest change in hue on heavy toasting and the least change on light toasting (Figure 12).

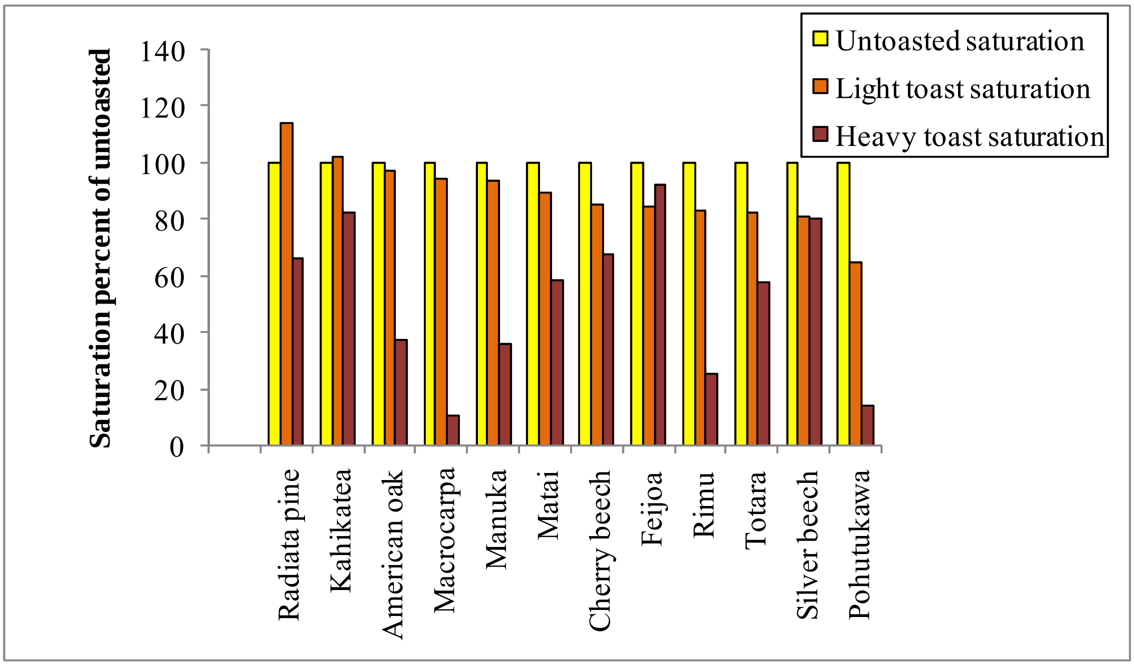

Figure 13 Colour saturation of woods at different toasting levels relative to untoasted saturation, and in descending order of light toasting values

The saturation, or intensity, of hue of most wood chips decreased on toasting and with intensity of toasting. The changes in saturation were greater than those lightness and hue angle. In other words, colour became 'washed out' i.e. the normalised saturation percent changed by up to 90%. There were exceptions to this. The saturation increased in radiata pine on light toasting, but subsequently showed a marked decrease on dark toasting. The saturation of kahikatea and American oak were unchanged on light toasting (Figure 13). Feijoa lost saturation when given light toast treatment but saturation increased on dark toasting. This behaviour was unique to feijoa.

On heavy toasting, macrocarpa and pohutukawa showed severe loss of saturation, closely followed by rimu. Of these three, macrocarpa and rimu were noted smoke generators on heavy toasting. Manuka and American oak also suffered a severe loss in colour saturation on heavy toasting.

When seen as photographs, the intensity of colour appears to increase on toasting, but the data in the colorimetric tables and figures shows that this appearance is more related to loss of light reflectance. In other words, true colour is usually being lost on toasting, not gained.

3.5 Infusion

Prior to infusion of wood chips in wine for two weeks, a vacuum was applied to the 1 L bottles containing the wood chips and a minimum volume of wine as described in Chapter 2. The aim was to remove air – or more importantly oxygen from the wood chips.

After five minutes the rate of bubbling due to dissolved gas was much reduced, but not zero because gas bubbles on the surface of chips subsequently appeared on storage. During storage some chips floated while some sank suggesting that remove of air was not complete. However, the residual oxygen from chips, and introduced oxygen from the decanting step, did not cause a problem because the wines were never described as oxidised in the qualitative/semi-quantitative trial (Chapter 4).

Chapter 4

Results for sensory evaluation

4.1 Introduction

As described in Chapter 2 the wooded wines which were evaluated in two ways, the first a qualitative/semi-quantitative trial, and the second a quantitative hedonic trial. Both are examined in this chapter. In the first trial the order or presentation and tasting was set, beginning with matai and ending with oak. This was done for logistic reasons and to reflect the way that wines are commercially evaluated. Evaluation of wines presented this way may have an order bias, which should not be forgotten in the following analysis.

4.2 Qualitative/semi-quantitative trial

4.2.1 Panelist behaviour

In the trial conducted at the Fine Wine Delivery Company, the nine experienced tasters performed their task without complaint, which is consistent with their occupation. At the AUT, many panelists commented that the task was arduous by the time they reached about the 12th wine. This was consistent with their relative inexperience, and suggests that the quality of evaluation may have lapsed for the latter wines. The liking task was included in the study because wine professionals are trained to differentiate between judgments of typicality on the one hand, and judgments concerning their own preferences and liking of a wine on the other. It was conceivable that some panelists would give low liking ratings to wines they perceived to be high in typicality with respect to the wine style under consideration (Parr, Green, White, & Sherlock, 2007).

4.2.2 Most liked and disliked treatments

For the qualitative/semi-quantitative trial there were 25 treatments. After data were marshalled into an Excel spreadsheet, that program was used to compute total most liked and most disliked results for each wood.

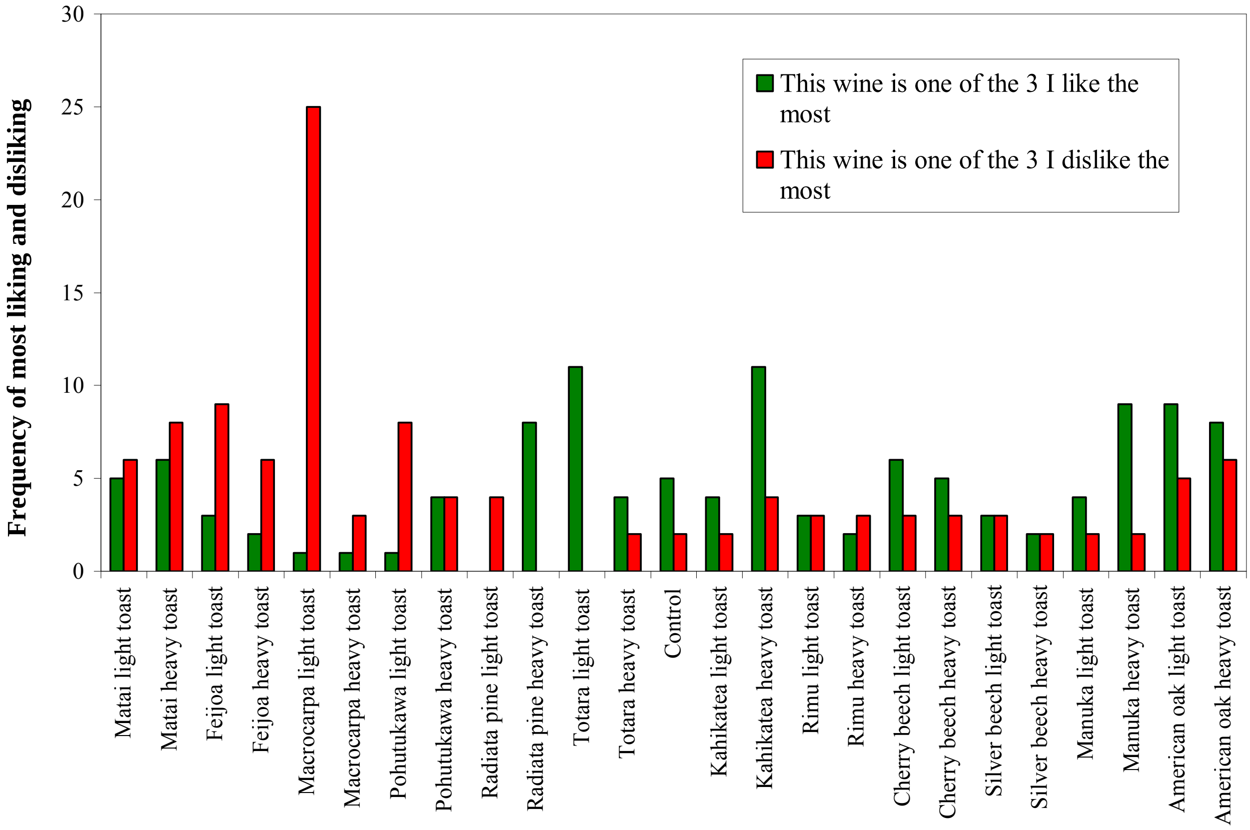

Figure 14 Selection frequency of three most liked and disliked wine treatments

Figure 14 shows the selection frequency of most liked and disliked wine treatments where panelists had to nominate the three they liked the most and the three they disliked the most. Totara light toast and kahikatea heavy toast were the two treatments most liked by the tasters. Among the 37 tasters, 11 included totara light toast and kahikatea heavy toast in their most liked group. (However, those who chose totara did not necessarily also choose kahikatea.) Ranked immediately below these two treatments were manuka heavy toast (9 panelists) and American light toast (9).

Macrocarpa light toast was markedly different from other treatments in that 25 tasters include it in their most disliked list. The next most disliked treatment was feijoa light toast with 9 nominations, then matai heavy toast and pohutukawa light toast (both 8).

A Chi-square analysis of the selection frequencies was highly significant ($P < 0.001$) as is obvious by inspection. The four woods contributing most to the difference between liking and disliking selection frequencies were macrocarpa light toast (16 %), totara light toast (8 %), radiata pine heavy toast (6 %) and pohutukawa light toast (4 %). Predictably these were the treatments where there was a strong like or dislike bias.

It was earlier noted that there could be an order bias in evaluation due to panelist fatigue. There is no test for this beyond inspection of the data. No trends were obvious between wines 1 and 25.

The ratio of the most liked to most disliked selection frequencies was calculated and plotted (Figure 15). Radiata pine heavy toast and totara light toast had zero nominations in the disliked group, and so the ratios for these two are infinite (expressed as 5 in Figure 15). Manuka heavy toast had the highest ratio, 4.5, all the treatments where the treatments were included in both groups. Kahikatea was the next highest scaled at 2.75. The control – no wood added – was recorded at 2.50 followed by totara heavy toast and cherry beech light toast, both 2.00.

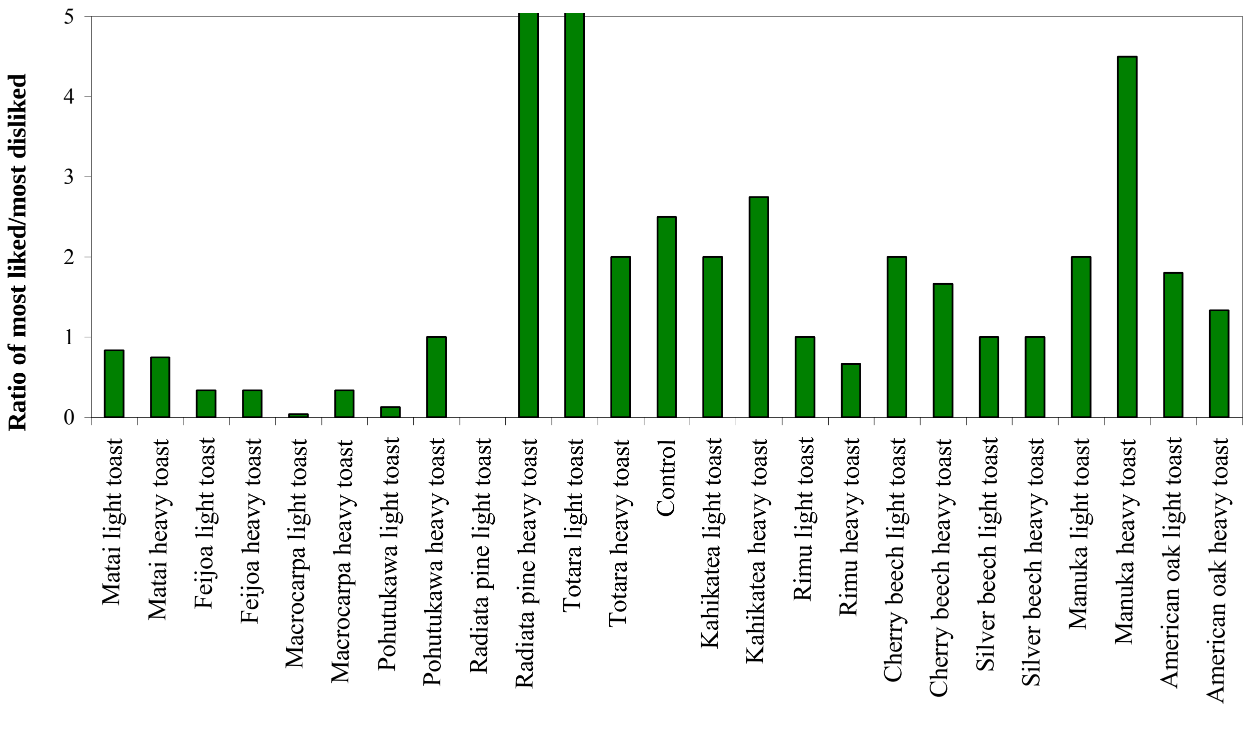

Figure 15 Ratio of the selection frequencies for the three most liked to the three most disliked wine treatments shown in Figure 14

4.2.3 Principal component analysis of nominated attributes

In the qualitative/semi-quantitative trial, panelists were asked to tick one or more of 14 boxes to describe the attributes that characterized each wood treatment of 25 (Appendix 3). In Figure 17, the frequency data has been transformed by principal component analysis

(PCA). Principal component analysis (PCA) is a technique for reducing a partially correlated symmetrical n-dimensional data set to an asymmetric set, such that new n-dimensions in the output convey different amounts of information. The first dimension conveys the most, the second the next most etc., so often a two-dimensional PCA plot of the first two dimensions – called principal components 1 and 2 – can portray much of the important information previously buried in the original data set.

The PCA plots (Minitab) presented in this thesis are scaled to portray the fraction of information contained in each dimension (principal component). Thus the two components represent 38 and 15 % of the information, so the ratio of the two axes is 38:15.

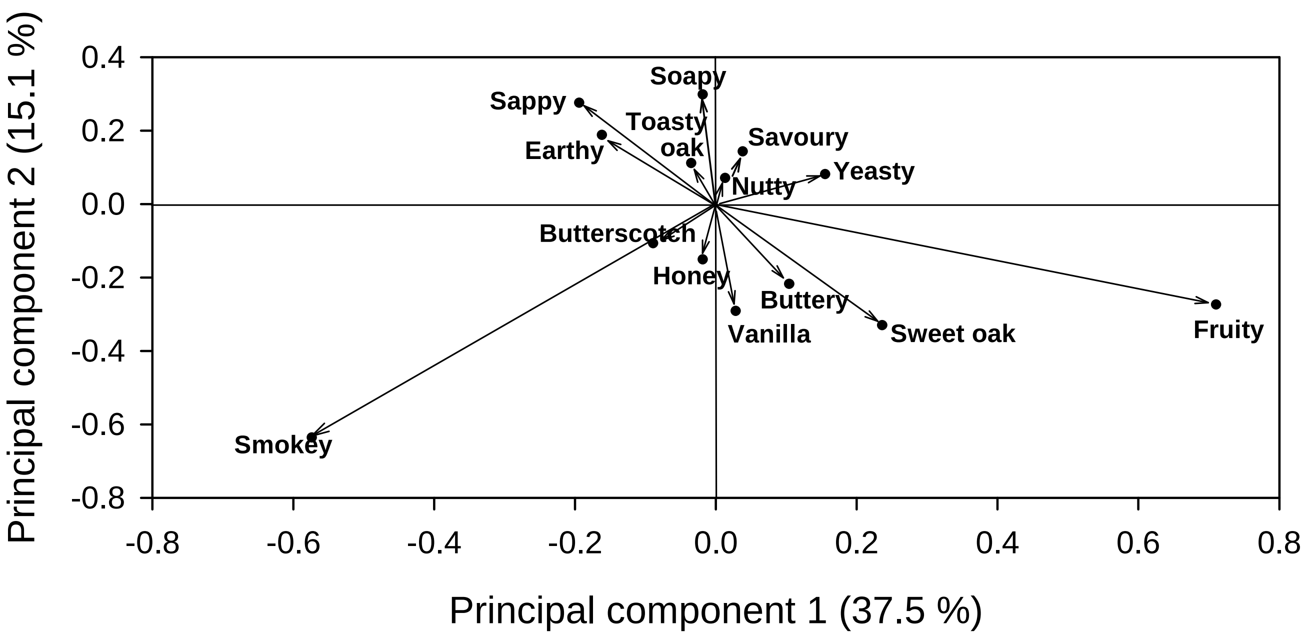

Figure 16 Principal component analysis of frequency data for descriptive attributes of 25 wood treatments

In Figure 16, 37.5 % of the information could be condensed into component 1. Thus these two components together portrayed 53 % of the total information, showing that there was extensive correlation in the attributes. (Thus, panelists ticking the ‘butterscotch’ box would tend to tick the ‘honey’ box).

Figure 16 shows that 'smokey' and 'fruity' are opposed to one another, implying that smokey notes in wine will negate fruity flavours. Sweeter notes like 'vanilla' and 'sweet oak' are opposed to 'sappy', 'earthy' and 'toasty oak'.

However, Figure 16 shows only the analysis of terms while Figure 17 shows the analysis of terms with superimposed attribute data. To achieve this, the score plot was scaled by a factor to approximately match the loading plot. This superimposition plot shows the wood treatment most linked to the attribute. For clarity, six treatments in this figure are represented by numbers alone as are only five of the 14 flavour attributes.

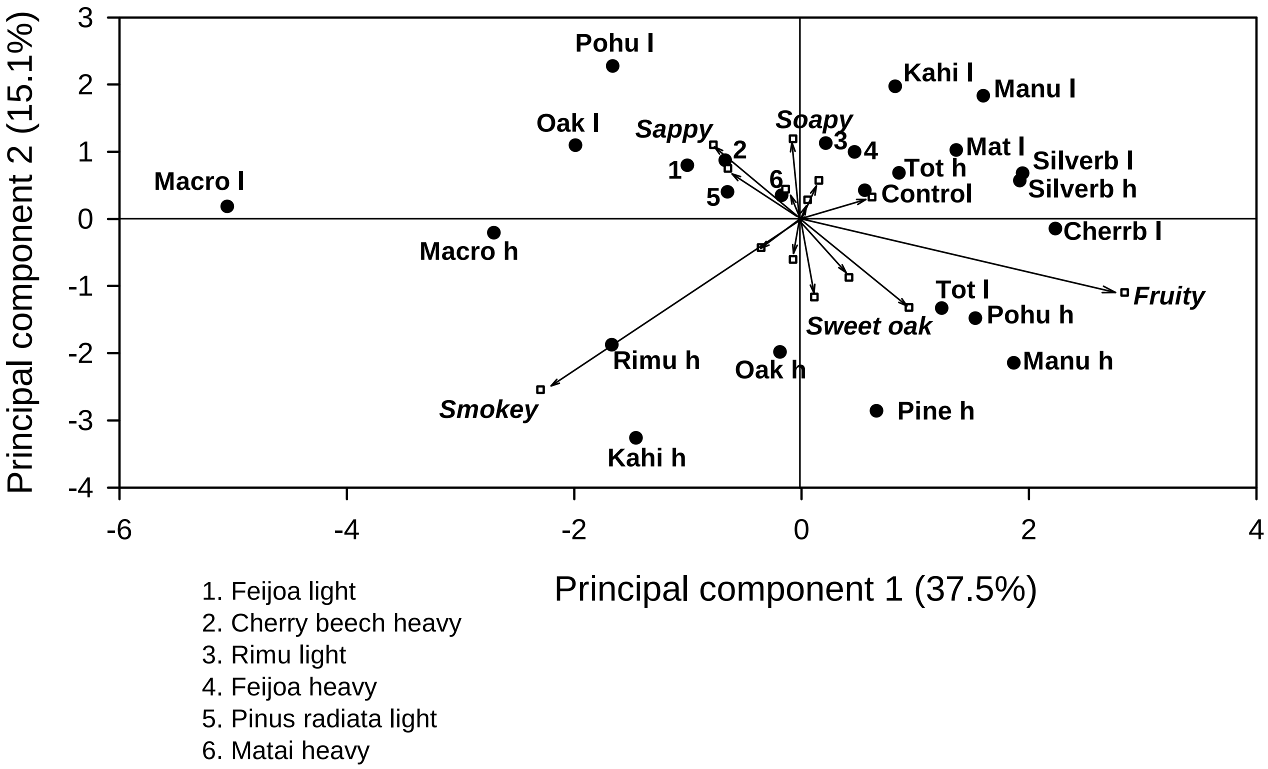

Figure 17 Principal component analysis of frequency data for descriptive attributes of 25 wood treatments, with loading and score plots superimposed. For clarity, only five of 14 attributes are labelled

In Figure 17 it can be seen that 'sweet oak' and 'fruity' flavour are associated with light and heavy toasted woods like cherry beech light, totara light, pohutukawa light, and manuka heavy. The heavy toasted treatments of rimu, American oak, and kahikatea were strongly associated with ‘smokey’ flavour. Macrocarpa light and heavy were placed strongly along the negative first principal component, but were not particularly associated with any flavour. It can be safely concluded that the negative first principal component was a strong indicator of disliked flavours because the strongly disliked macrocarpa light toast treatments was at the axis’ extreme.

The grouping of treatments in the upper right quadrant, which included the control, did not follow any obvious pattern of species and toasting, but were linked to ‘savoury’, ‘nutty’ and ‘yeasty’ flavours, flavours which are plausibly linked by flavour chemistry (Belitz, 1999). ‘Sappy’ and ‘soapy’ flavours were associated with American oak light, pohutukawa light, and other treatments that again followed no obvious pattern. What is striking however, is the tendency for different toasting levels to associate with different flavour attributes in different quadrants, well illustrated by pohutukawa light and heavy (top left and bottom right). But this tendency was not universal, as shown by silver beech light and heavy, which were almost superimposed.

A fundamental question may be asked. Was the wood used a more important determinant of flavour attribute than the level of toasting? This question was answered by colour coding the wood treatments for degree of toasting (Figure 18). Principal component 2, representing 15.1 % of the information, clearly resolved the treatments into degree of toasting, confirming that the organoleptic sensation resulting from the use of chips at the different toasting levels can be different (Phillips, 2001). Thus, light toasting (red symbols) tended to occupy the positive quadrants and heavy toasting (brown) the negative. Clearly degree of toasting is important for nearly all woods, but Principal component 1, which represents more than double the information, presented a more complex picture. Five of the wood toasting pairs were located on the two negative or the two positive quadrants (macrocarpa, totara, silver beech, manuka, American oak) whereas the other seven wood pairs were located in negative and positive quadrants. In other words, irrespective of toasting level those five woods returned much the same flavour profile. In the case of macrocarpa, which was intensely disliked (Figure 14), this might be explained by a lingering resinous flavour (see next section) that toasting did not eliminate. As for the other species, it seems likely that heavy toasting affected flavour quantitatively, but not qualitatively.

Totara, manuka, and American oak were later assessed in the hedonic trial (see later). Inclusion of those woods in that trial was based on liking and disliking (Table 8), and not on the (subsequent) principal components analysis presented above. However, links between behaviour on toasting and liking remain obscure.

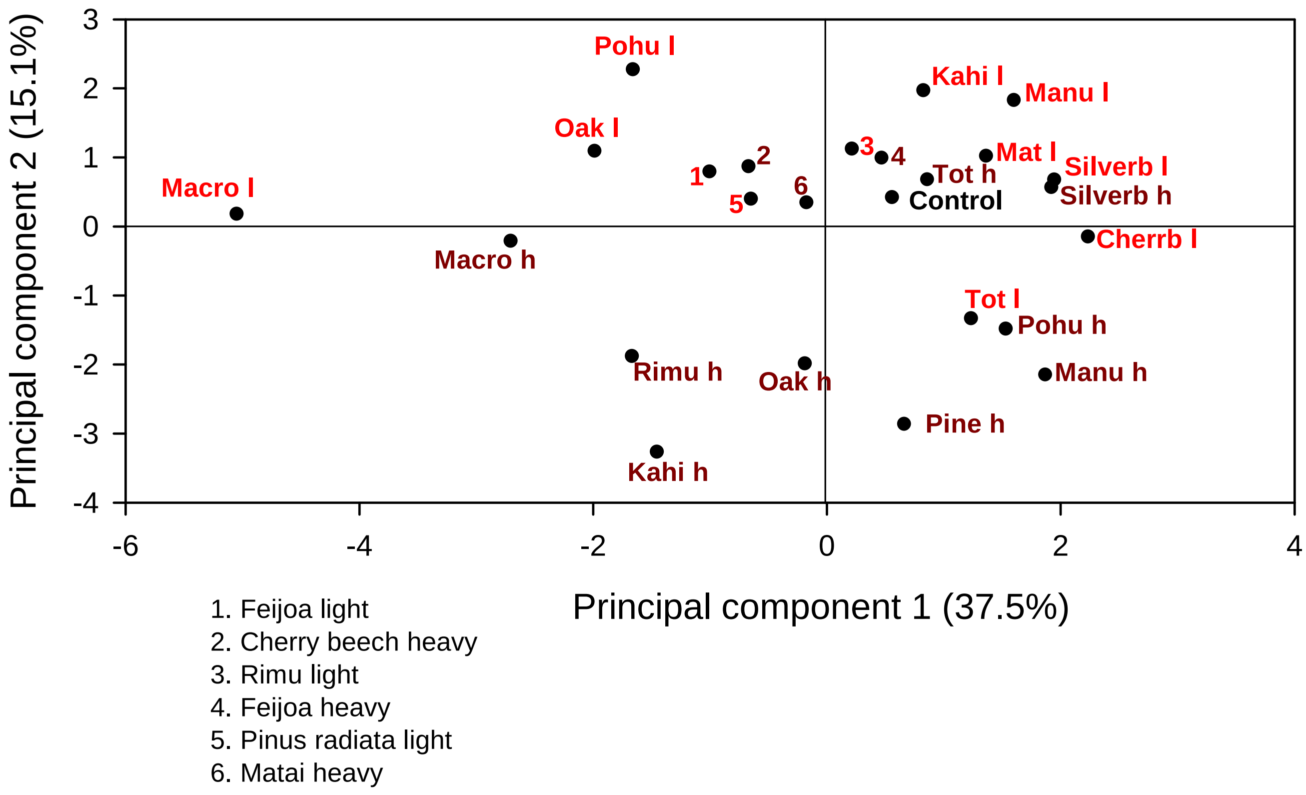

Figure 18 Colour coding of the wood treatments in the principle components plot

4.2.4 Analysis of terms used in semi-quantitative analysis

Table 6 shows the number of times the 'Other' box was completed for each wood treatment or was ticked with no comment added. The latter was interpreted as the panelist noting a flavour but being unable or unwilling to describe a term. The total number of 'Other' responses (comments plus ticks) varied from a low of one for radiata pine heavy toast to a high of 18 for macrocarpa light. A high comment frequency was also recorded for both feijoa toasts, pohutukawa light, and radiata light toast.

Table 6 'Other' comments and ticks made on treatments of wooded wines

Treatment	Number of descriptive comments in 'Other' category	Number of times the 'Other' box was ticked with no comment	Total 'Other', comments and ticks
Matai light toast	5	1	6
Matai heavy toast	7	1	8
Feijoa light toast	11	2	13
Feijoa heavy toast	9	1	10
Macrocarpa light toast	14	4	18
Macrocarpa heavy toast	8	1	9
Pohutukawa light toast	11	1	12
Pohutukawa heavy toast	4	0	4
Radiata pine light toast	9	2	11
Radiata pine heavy toast	1	0	1
Totara light toast	7	2	9
Totara heavy toast	3	0	3
Control	4	2	6
Kahikatea light toast	7	0	7
Kahikatea heavy toast	3	5	8
Rimu light toast	5	0	5
Rimu heavy toast	4	1	5
Cherry beech light toast	7	0	7
Cherry beech heavy toast	4	1	5
Silver beech light toast	4	1	5
Silver beech heavy toast	3	0	3
Manuka light toast	5	0	5
Manuka heavy toast	5	1	6
Amer. oak light toast	5	4	9
Amer. oak heavy toast	8	0	8

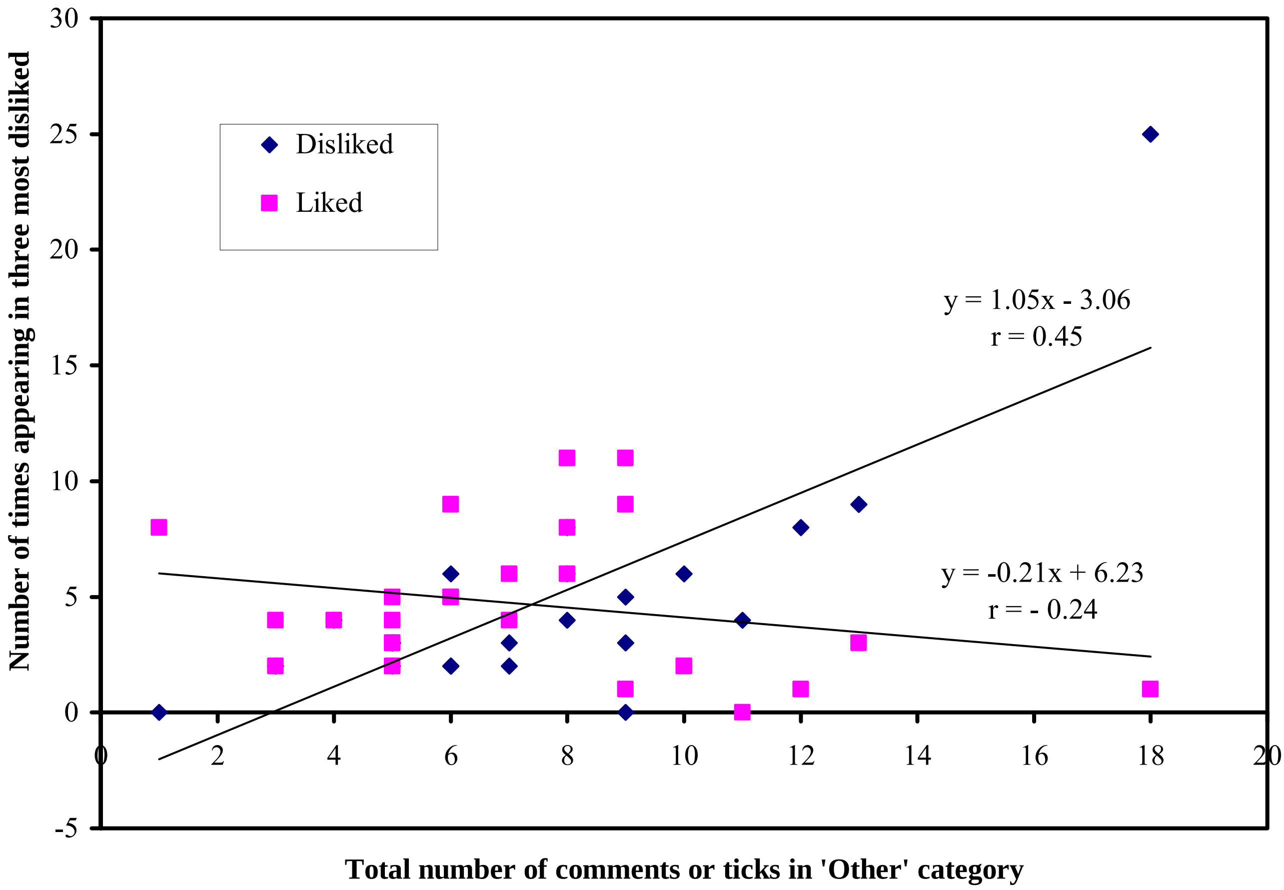

Figure 19 Plot of the three most liked and three most disliked data against total 'Other' comments

Figure 19 plots the number of times a treatment appeared in the three most liked and three most disliked groups against total 'Other' in Table 6. Least squares lines of best fit were calculated for these two data sets. Generally, the more comments that were made, the more the wine was more likely to appear in a panelist's three most disliked group (r = 0.45). Comments were a poorer indicator of the three most liked (r = –0.24). Equivalent plots of numbers of comments alone showed the same trends (data not shown).

Table 7 shows the ratio of number of descriptive comments for light to heavy toasts. All were greater than unity except for matai and American oak, suggesting that there were usually more extractable flavours that panelist's thought worth commenting on from light toasting.

Table 7 Ratio of number of descriptive comments for light and heavy toasts

Treatment	Number of comments for light divided by the number of comments for heavy
Matai	0.71
Feijoa	1.22
Macrocarpa	1.75
Pohutukawa	2.75
Radiata pine	9.00
Totara light toast	2.33
Kahikatea	2.33
Rimu light toast	1.25
Cherry beech	1.75
Silver beech	1.33
Manuka	1.00
American oak	0.63

Each treatment elicited unique descriptors as well as many that were common to several treatments (Appendix 4). This suggests the presence of similar extracted compounds in some treatments. Treatments like kahikatea light toast had some unique comments like ‘grassy’, ‘waxy’; feijoa heavy toast had unique comments like ‘rubbery’, ‘steely’. Kahikatea heavy toast elicited a ‘smoked bacon’ comment. The terms ‘acidic’, ‘sour’ and ‘salty’ were common for some treatments like matai light toast, totara heavy toast, and manuka light toast. Manuka elicited ‘creamy fat’ and ‘limey’ notes as unique descriptors.

Totara, pohutukawa and kahikatea were interesting in another respect. Their descriptors were similar to those applied to American oak of which contain six descriptors and with frequencies the same as that reported for the American oak. This suggests that these four woods were yielding similar flavours.

Macrocarpa light toast was particularly interesting as it was also the most disliked treatment. It showed the highest number of attributes such as ‘oak chip repugnant pine’, ‘vegetative’, ‘limey’, ‘resin’, ‘paint stripper’, ‘woody’, ‘sour’, ‘plastic’, ‘harsh’, ‘deadly’, as well as three references to pencil sharpening. The number of comments reduced after that wood was heavily toasted, but the curious descriptions relating to pencils were retained (independently) by three panelists. This descriptor may derive from the origins of softwood used in pencil manufacturing, which includes cedar (Anonymous, n.d.-a) which has a low resin content enabling pencil makers to manufacture high quality pencils with a smooth surface that sharpens easily.

Pohutukawa and feijoa elicited descriptors like ‘cork’, ‘tart smell’, ‘misty’, ‘sour’, ‘ripe’, ‘oily’, ‘plastic’, ‘fungus’, ‘unpleasant taste’, ‘bitter/caffeine’, ‘apple’, ‘musty’, ‘acidic’ and ‘salty’. Feijoa light toast also elicited ‘chemically’, ‘sharp’, ‘bland’, and ‘cider-like’.

Toasting increases the quantities of some of these compounds and also leads to the formation of other new compounds. Furanic aldehydes, caused by carbohydrate degradation and responsible for the “toasty” aromas, and lignin degradation compounds (vanillin, siringaldehyde, guaiacol) tend to be formed during the toasting process. Other compounds produced by Maillard reactions, such as maltol, cyclotene and furaneol, have been correlated with descriptors, such as toasty, burnt sugar and fruity-caramel (Guchu et al., 2006).

In the case of white wines, the use of oak chips could avoid the oxidation aromas and colour changes produced during barrel aging, and impart oak notes to wines without decreasing the fresh and fruity characteristics.

Smoke aroma could have been produced by volatile phenols, such as guaiacol and its derivatives, and toasty aroma by furan derivatives or compounds formed by Maillard reaction (Guchu et al., 2006).

4.3 Choice of wines for the hedonic trial

In seeking to quantify liking of the various wood treatments by consumers, the initial 25 treatments were thinned to six, which is about the limit that could be applied to volunteer consumers in wine shops. The control was one obvious choice. Radiata pine heavy toast elicited only one (negative) attribute (Appendix 4) was generally liked (Figure 14), and was moreover a wood strongly associated with New Zealand. Totara light toast was well liked and never appeared in the three most disliked categories (Figure 14). It is also a New Zealand icon. However, it did elicit some negative comments. Kahikatea heavy toast had an unusual flavour profile, eliciting ‘fatty’, and ‘smoked bacon’ and ‘sour’ attributes (Appendix 4). This treatment was also one of the most liked wines. Among the descriptors for manuka heavy toast was ‘creamy fat’ which might be interpreted as a buttery attribute, a term commonly applied to oaked chardonnays. Manuka was also well liked, is commonly used as a smoking wood and again is an icon. The sixth wood was American oak. The light toast treatments were chosen because Table 7 showed that they yielded relatively more flavour than the heavy toasts.

4.4 Mean likings for quantitative hedonic trial

In the hedonic trials, the likings and disliking were based on a nine-point hedonic scale, in which consumers had to tick to indicate choice (Appendix 5). At each wine shop 30 panelists completed the ballot, making 180 responses in all. The consumers also had to identify their gender, and age in three ranges, 18 to 30 years, 31 to 45, and 46 and older. These were 62 consumers in age-group 18-30, 57 in 31 to 45, and 61 in 46 and older; while there were 127 males and 53 females (Appendix 6). They were encouraged to make comments, although few did.

Table 8 shows the means and the main statistical effects in the hedonic trial. There was an overall significant effect ($P < 0.001$) for treatment, indicating that some wine(s) were liked more than the others. The most liked wines were totara (6.49) and the control treatments (6.33) which were statistically the same. There was no statistical difference between the other four wines, which included American oak.

There was an overall statistical effect of outlet ($P = 0.032$), but the relatively conservative Tukey multiple range test revealed no significant differences between individual outlets. Overall outlet as a factor was not important.

Older consumers (46 years +) liked the wines more than younger consumers, and the overall effect of age was significant at $P = 0.034$. Wine is the most frequently consumed alcoholic drink and more is consumed by older New Zealanders than younger (Niki Stefanogiannis, and, & Yeh, 2007).

Females liking scores was higher than those of males, by a large margin (6.30 versus 5.86) ($P < 0.001$). The reason for this is not known.

In the year 1995, general population survey of persons from age 14 to age 65, males ages 18 to 24 years were over-represented in the heaviest drinking 10 per cent, comprising 33 percent of the heaviest drinkers but only 9 per cent of the total survey (Jernigan, 2001). Eight out of ten New Zealanders consume alcohol. Europeans drink more than other ethnic groups (Niki Stefanogiannis et al., 2007).

Table 8 Means and main statistical effects for the hedonic trial of the six wooded wines

		Treatment (6[1])				Overall statistical effect
Kahikatea	American oak	Totara	Manuka	Radiata pine	Control	
5.69[a]	5.88[a]	6.49[b]	6.04[a]	5.47[a]	6.33[b]	*P* < 0.001
		Outlet (6)				
Balmoral	Parkland's	Village Winery	Thirsty Frog	Wine Vault	Greenlane	
5.78[a]	6.18[a]	5.81[a]	5.90[a]	6.04[a]	6.19[a]	*P* = 0.032
		Age group (3)				
18 to 30 (62)		31 to 45 (57)		46 and older (61)		
5.84[a]		5.96[a]		6.15[b]		*P* = 0.034
		Gender (2)				
Male (127)				Female (53)		
5.86				6.30		*P* < 0.001
		Consumer (180)				
		5.98				*P* < 0.001

[a], [b]: Means in the same row with a different superscript are significantly different at *P* < 0.05

[1] : Numbers in parentheses indicate numbers in each category

The statistical interactions were particularly interesting. All were non-significant (Table 9) meaning that at no outlet was a particular wine favoured, and the two genders liked the wines equally overall. However, there was a hint (*P* = 0.16) that consumers of different age groups had different treatment preferences.

Table 9 Statistical interactions for the hedonic trial

Interaction	Statistical effect
Treatment x outlet	$P = 0.99$
Treatment x age group	$P = 0.16$
Treatment x gender	$P = 0.70$

4.4.1 Analysis of terms used in quantitative hedonic trial

In the hedonic trials the panelists were encouraged to make comments, although few did. The comments, with names substituted for the blinding codes, are present in Table 10 below.

Table 10 Comments made for quantitative hedonic trial. Treatment names have been substituted for three-digit blinding codes

Gender	Age group	Comments	Referring to
Female	46 and older	Very refreshing if chilled. Not robust which I prefer.	All treatments
Female	46 and older	Good a palatable wine with white flesh i.e. chicken and fish	All treatments
Male	18 to 30	Where are you getting these wines from?	All treatments
Male	46 and older	Wines totara and control are of better 'sweetish' taste whereas radiata pine and kahikatea rather smell more of alcohol than wine	Kahikatea, totara, radiata pine, control
Female	18 to 30	They all tasted the same. Not much of a white wine fan	All treatments
Female	31 to 45	Very similar in taste but control did seem sweeter which I liked	Control
Male	31 to 45	Good survey. Hope you do well. Wines American oak and kahikatea not very good.	Kahikatea, American oak
Male	31 to 45	Manuka: heavy oak, light fruit; kahikatea: nice balance; radiata pine: nice oak; American oak: don't like (American oak); Control: bit bitter; totara: good balance and length	Kahikatea, American oak, totara, manuka, radiata pine, control
Male	31 to 45	American oak disliked a lot	American oak
Female	46 and older	Manuka really nice overshadowed the rest	Manuka
Male	46 and older	Radiata pine and totara has a strong flavour and woody smell and also fruity, smooth and different.	Radiata pine
Male	31 to 45	Sauvignon blanc rules	All treatments

From the Table 10, it can be seen that there was no obvious pattern of liking. As shown in the last column, all the comments referred to the wines collectively except some where the wine names were specified. There was also no particular pattern with gender or age group, except that the 31 to 45 and 46 and older age groups dominated comments, while the consumers were spread nearly equally among the three age groups. It was also seen that

American oak which might be expected to be consistently liked was particularly prominent in dislike comments consumers. Totara, control and manuka treatments were received more positive comments.

Chapter 5

Overall discussion and conclusion

This chapter attempts to draw together the choice of woods, the physical data obtained on toasting the 12 woods and the flavour outcomes in the two sensory trials. It also briefly examines the commercial opportunities.

The choice of woods was based on availability, iconic nature, and vague associations of wood with food. The geographical origin of the woods collected were usually unknown, but at this stage of research the subtleties of climate and soil effects are relatively unimportant, but may not be if commercial goals were pursued. Thus, a tree originating from a colder region within New Zealand will be slower growing with a higher density and different wood composition. Within the natural occurrence range of a tree species, specimens grow more quickly in warmer, wetter regions than in colder, drier regions (Girardin, Raulier, Bernier, & Tardif, 2008). In the latter the summer/autumn wood denser fraction of the wood occupies more of the growth ring.

The American oak used was not sourced from a wine company and its intended use in New Zealand could be anything but wine. According to industry claims (Hurt, 1999) regions and growing conditions of oak are important in the resulting wine maturation process. However, the truth of these claims may never be known because of industry secrecy and a need to maintain an aura of exclusivity to command high prices.

Wood chip preparation was labour intensive, because the cutting was done to obtain uniformly sized chips suited to the one litre scale of infusion. The logic of this approach was that infusion is a surface area phenomenon. This is clear from(P. Arapitsas et al., 2004), the fact that small oak barrels are used for premium wines and the fact that comminuted toasted oak for infusion in wine is available in a wide range of small sizes. (However, the scientific literature is remarkably vague on the depth to which wine will penetrate wood. Empirical results have dictated commercial offerings.)

On drying and toasting each wood was largely a unique story as determined by moisture content, weight loss and colour changes, although with some similarity between botanically related woods. For example, the two beeches behaved similarly. However, there were completely unexplained differences, such as the propensity for some woods to catch fire. Thus macrocarpa and rimu both ignited during heavy toasting while others did not. Macrocarpa at least is an aromatic wood, suggesting high resin content. That resin would almost certainly be volatile at those temperatures, and reach the flash point where oxygen was also available. Equally though other woods might be resinous.

The weight loss of oak chips at 200°C was much greater than that of other woods, but the colour change did not indicate losses due to severe charring. Interestingly, the moisture content of oak (determined by drying to a relatively cool 110°C) was the lowest of all the woods, and it might be argued that oak had 'head start' in pyrolysis. However, it is reasoned that exposure to 200°C would rapidly drive off all free water within tens of minutes. Other woods that showed severe weight loss on dark toasting (rimu, macrocarpa) did char severely. Overall each wood behaved in a distinctive way to these toasting treatments, but with some botanical similarity between cherry and silver beech.

The daylight colour parameters, L*, a*, and b* were measured and the latter two converted to the more meaningful values of hue and saturation. Overall, hue was the least affected, indicating that the basic colour of the woods was little changed by toasting. Light and saturation generally decreased strongly, particularly on heavy toasting. Colour was thus being lost and less light reflected.

As interesting as the physical changes in wood chips to toasting are, with one clear exception they bore no obvious relationship to flavour. The exception was the clear effect that whatever the wood, the flavour from light and heavy toast treatments could be easily distinguished in the same way as they can be for oak (Bozalongo et al., 2007). In this respect, a sensory descriptive analysis of wines with oak chips showed that the degree of toasting of oak chips used had a greater effect than the type of oak used to make the chips (Bozalongo et al., 2007). The clear distinction between light and heavy toasting results is supported by a recent thesis (Kaushal, 2007). Kaushal reports that the visible colour in white wine and an artificial wine (tartarate, ethanol, water) was unaffected by toasted wood infusion. However, there were major changes in the ultraviolet range (200 to 400 nm). As a group, lightly toasted woods produced much more wine-soluble absorbing matter than heavily toasted woods, supporting the use of light toast woods in the hedonic trial.

The choice of wood for the hedonic trial excluded disliked woods, macrocarpa being the best example. Inclusion of disliked woods would have expanded the dynamic range of the hedonic trial, but were excluded because the choice of woods was aimed at commercial possibilities, and a maximum of six treatments could be realistically tested. In the trial there were 180 consumers. Whereas this might seem a large number it must be realised that there a wide range of ages was represented. Wine liking is often affected by demographic factors, and in the present experiment age group as a factor was statistically significant. The oldest category, 46 years and older (61 consumers) clearly liking the wines more than younger people. The interaction of treatment x age group was not statistically significant ($P = 0.16$), but this level hints at some complexity within age group and treatment, such that future hedonic trials might better be aimed at narrower demographic groups, at the same time maintaining a large number of responses.

Overall however, it seems clear that the two most-liked wooded wines were the totara and manuka treatments. Totara is a protected species and although previously milled totara is routinely offered for sale, particularly on the online auction site New Zealand's Trademe[1], a guaranteed supply would be required for commercial exploitation. Moreover, recycled totara comes in many different shapes and forms, and some will be varnished or painted. Most supplies of living totara suitable for timber use are now exhausted particularly as most of the indigenous lowland forest has been replaced by pastoral farming, exotic plantation forestry and urban development. Totara remaining on Crown land is primarily in montane forest and is managed for conservation purposes. Only small quantities are available from private or multiply-owned Maori lands. Interest has been increasing, therefore, in establishing and managing plantations of totara (and other indigenous timber species), for market and non-market benefits. Protection legislation might be circumvented by growing the species as a crop, but the production cycle would be many years. In this respect Northern New Zealand totara grows faster than southern totara (Bergin, 2008).

This leaves manuka as the distinct commercial possibility. Manuka grows prolifically through both islands of New Zealand (Maddocks-Jennings, 2005). It is not usually protected on private land and is already available in chip and sawdust forms for food smoking purposes. Manuka is widely available in wood yards and the price reflects its firewood value. To be used commercially in the wine industry a consistent supply and a means of toasting would need to be identified. Wine industry personnel could not be expected to produce toasted wood chips. Thus, there are significant barriers to introducing manuka as a means of

[1] On 30 April 2008 no fewer than 14 auctions were displayed for recycled totara from a variety of New Zealand sources

flavouring wine, and these extend to perceptions of oak barrels and wood chips, and to market access, both in New Zealand and overseas.

A label claim that manuka chips were used may have a negative effect given that the industry never makes claims to using any chips in production because the romance of barrels and cellars dominates popular beliefs. On the other hand an experimental commercial trial could be done within an academic framework but linked to a winery that would limit costs while exploring a new flavour dimension in wine.

World food markets are governed by a strong framework of rules to ensure consumer safety and New Zealand is no exception, governed as it is Food Standards Australia New Zealand. A detailed search of the Australia New Zealand Food Standards Code has revealed no rules governing wood in wine (Canberra and Wellington, New Zealand). The code for wine (2.2.3), (2.7.1), and (2.7.4) make no reference to wood in wine (NZFSA, 2008). Arguably a manuka-infused wine could be produced and marketed without restriction. Moreover, the long history of manuka smoke in New Zealand foods, principally fish, would suggest it is safe to use. Internationally however, the rules may be restrictive, and could provide a platform for non-tariff barriers, on the basis that there is no long term evidence of safety. Thus market access issues remain an unknown.

Finally, it can be concluded that favourable wood-infusion flavours in wine is not restricted to oak. A range of other species, in the form of chips rather than barrels, can perform as well, if not better than oak. This finding opens a range of research and commercial possibilities. The possibilities are not limited to wine. What is not commonly realised is that whisky derives nearly all its flavour from oak barrels, into which relatively flavourless, clear and colourless grain spirit is placed for maturation. There is no reason why toasted manuka or other wood chips could fulfill a similar role with parallel but distinct flavour outcomes. That research will be pursued by future AUT students.

Appendices

Appendix 1 Colorimetric tables showing lightness, hue and saturation values at different toasting levels

Mean lightness for woods at different toasting levels

	Lightness L*		
Wood	Untoasted	Light toast	Heavy toast
Matai	59.53	50.93	29.96
Feijoa	59.05	33.43	31.80
Macrocarpa	64.82	55.70	16.33
Pohutukawa	56.55	30.03	15.82
Radiata pine	64.55	64.55	26.43
Totara	47.81	37.70	27.59
Kahikatea	68.48	59.28	39.23
Rimu	48.90	41.57	22.70
Cherry beech	54.49	45.53	29.07
Silver beech	60.17	50.16	34.66
Manuka	59.61	50.27	19.51
American oak	46.46	43.39	23.14
Means ± SD	57.53 ± 7.02	46.88 ± 10.33	26.35 ± 7.19

Mean hue angle for woods at different toasting levels

	Hue angle (arctan b*/a*)		
Wood	Untoasted	Light toast	Heavy toast
Matai	1.20	1.16	1.06
Feijoa	1.29	1.06	1.07
Macrocarpa	1.16	1.23	0.76
Pohutukawa	1.07	0.82	0.82
Radiata pine	1.29	1.35	1.01
Totara	1.02	0.99	1.00
Kahikatea	1.32	1.29	1.15
Rimu	1.12	1.12	0.99
Cherry beech	0.95	0.99	0.99
Silver beech	1.09	1.07	1.08
Manuka	1.13	1.08	0.85
American oak	1.20	1.24	0.95
Means ± SD	1.15 ± 0.11	1.17 ± 0.15	0.98 ± 0.16

Mean saturation values for woods at different toasting levels

	Saturation ($\sqrt{(a^2 + b^2)}$)		
Wood	Untoasted	Light toast	Heavy toast
Matai	31.12	27.78	18.11
Feijoa	20.68	17.40	19.10
Macrocarpa	28.21	26.50	3.00
Pohutukawa	21.01	13.60	3.00
Radiata pine	20.68	23.64	13.72
Totara	24.82	20.37	14.28
Kahikatea	28.11	28.60	23.10
Rimu	26.49	22.03	6.63
Cherry beech	21.71	18.50	14.70
Silver beech	20.74	16.84	16.68
Manuka	21.33	20.00	7.70
American oak	19.67	19.12	7.37
Means ± SD	23.71± 3.86	21.20 ± 4.64	12.30 ± 6.59

Appendix 2 Ballot for qualitative/semi quantitative analysis of wooded wines

Ballot number by (name) ____________________

Please tick boxes that best describe your opinion. You may tick more than one box. If your description is not in the list, write your opinion in the "Other" box

This wine is one of the 3 **I like the most**	This wine is one of the 3 **I dislike the most**	Wine number	Description													
			Sweet oak	Toasty oak	Smokey	Vanilla	Butter-scotch	Buttery	Fruity	Soapy	Honey	Savoury	Yeasty	Nutty	Earthy	Sappy	Other
		1															
		2															
		3															
		4															
		5															
		6															
		7															
		8															
		9															
		10															
		11															
		12															
		13															
		14															
		15															
		16															
		17															
		18															
		19															
		20															
		21															
		22															
		23															
		24															
		25															

Appendix 3 Results for qualitative/semi quantitative analysis of wooded wines

This wine is one of the 3 <u>I like the most</u>	**This wine is one of the 3 <u>I dislike the most</u>**	**Wine number**		**Description**													
This wine is one of the 3 I like the most	This wine is one of the 3 I dislike the most			**Sweet oak**	**Toasty oak**	**Smokey**	**Vanilla**	**Butter-scotch**	**Buttery**	**Fruity**	**Soapy**	**Honey**	**Savoury**	**Yeasty**	**Nutty**	**Earthy**	**Sappy**
5	6	**1**		7	4	3	6	1	1	16	5	3	3	3	2	0	5
6	8	**2**		4	9	6	2	4	3	8	3	1	3	5	2	2	4
3	9	**3**		4	4	5	4	0	1	5	2	1	3	4	1	4	6
2	6	**4**		7	6	3	3	1	0	9	4	1	3	2	2	1	2
1	25	**5**		1	6	15	1	1	0	0	5	2	2	2	0	6	10
1	3	**6**		2	6	5	1	3	1	4	4	5	4	0	3	6	3
1	8	**7**		4	5	0	3	1	0	6	5	1	4	6	4	7	7
4	4	**8**		7	6	7	4	4	6	10	0	3	5	3	4	3	3
0	4	**9**		5	3	2	4	5	0	8	4	0	3	4	3	5	4
8	0	**10**		8	7	14	8	3	2	6	3	4	2	2	3	2	1
11	0	**11**		7	3	2	6	6	3	13	2	5	1	4	0	3	4
4	2	**12**		4	4	5	3	2	2	13	2	3	4	5	4	3	2
5	2	**13**		10	2	3	1	2	6	11	3	3	3	2	0	4	6
4	2	**14**		6	7	4	3	0	0	13	2	0	3	7	2	5	4
11	4	**15**		5	2	14	5	4	4	5	0	5	2	1	3	5	7
3	3	**16**		7	4	6	4	0	1	12	2	2	6	3	3	5	4
2	3	**17**		5	7	9	5	5	1	4	2	4	3	2	2	5	6
6	3	**18**		7	1	3	6	1	5	15	2	3	2	4	2	2	4
5	3	**19**		5	4	4	2	3	2	10	4	10	6	3	0	0	7
3	3	**20**		6	5	3	3	0	6	16	2	2	3	3	3	2	3
2	2	**21**		9	8	5	5	1	2	13	3	4	4	6	3	4	2
4	2	**22**		7	10	0	2	0	3	13	3	4	4	5	2	2	3
9	2	**23**		11	9	5	4	5	1	10	1	5	0	5	4	6	1
9	5	**24**		6	6	3	2	4	3	10	7	5	6	2	5	5	9
8	6	**25**		4	10	2	7	3	5	6	4	5	2	2	9	4	5

Appendix 4 Descriptions applied to wine treatments in the qualitative/semi quantitative analysis

Appendix 1 Descriptions applied to wine treatments in the semi quantitative/qualitative analysis

Treatments	Descriptive words									
Matai light toast	Flowery	Sour	Acidic	Bland	Dry					
Matai Heavy toast	Tasteless	Citric	Bland	Bitter	Sharp	Acidic	Barley-like			
Feijoa Light toast	Fat malo	Sour	Tart	Salty	Chemically	Sharp	Bland	Acidic	Cider-like	Sharp	Acidic/tar
Feijoa heavy toast	Bland	Steely	Unripe, bitter	Rubbery	Citrus	Bland	Acidic	Sweet	Weak taste		
Macrocarpa light toast	Oak repungent pine	Vegetative	Limey	Pine	Resin	Pencil sharpenin gs	Paint stripper	Woody	Sour	Plastic	Harsh
Macrocarpa heavy toast	Sour	Pencil sharpenings	Citrus	Woody	Unpleasant taste	Chemical	Sharp	Graphite, pencil lead			
Pohutukawa light toast	Cork tart	Misty	Sour, unripe	Oily	Plastic	Fungus	Unpleasant taste	Bitter/caffeine	Apple, musty	Acidic	Salty
Pohutukawa heavy toast	Acidic	Sour	Ether	Salty							
Radiata pine light toast	Weak, thin green, sour	Citrus	Sharp	Bland	Acidic	Sour	Woody	Salty	Bitter		
Radiata pine heavy toast	Acidic										
Totara light toast	Flowery	Sour	Tasteless	Bitter	Acidic	Salty	Wax				
Totara heavy toast	Sour	Citrus	Acidic								
Control	Lemon	Oily	Acidic	Sour							
Kahikatea light toast	Cork tart	Sour	Waxy	Grassy	Too oaky	Salty	Acidic				
Kahikatea heavy toast	Fat	Smoked Bacon	Sour								
Rimu light toast	Dry	Tasteless	Harsh	Acidic	Chemical						
Rimu heavy toast	Resin	Sour	Harsh	Sour							
Cherry beech light toast	Dry	Tart	Oily	Acidic	Watery sour	Sour	Salty				
Cherry beech heavy toast	Salty		Citrus	Bland	Acidic						
Silver beech light toast	Under ripe fruit poor oak	Sour	Acidic	Too strong like acetone							
Silver beech heavy toast	Bland	Cinnamon	Spice								
Manuka light toast	Limey	Sour	Harsh	Acidic	Sour						
Manuka heavy toast	Creamy fat	Limey	Salty	Tart	Salty						
Amer. oak light toast	Very sickening	Phenolic	Woody, oily	Aromatic	Too oaky						
Amer. oak heavy toast	Marzipan confectionate	Woody	Citrus	Sharp	Sour	Acidic	A bit too oaky	Liquorice			

Appendix 5 Ballot for liking and disliking; nine point hedonic scale of wooded wines

Gender: M ☐ F ☐

Age range: 18- 30 ☐ 31- 45 ☐ 46 and older ☐

How much do you like each of these wines?

Taste from left to right

For each wine tick the box that best describes your liking/disliking

Like extremely	☐	☐	☐	☐	☐	☐
Like a lot	☐	☐	☐	☐	☐	☐
Like moderately	☐	☐	☐	☐	☐	☐
Like slightly	☐	☐	☐	☐	☐	☐
Neither like nor dislike	☐	☐	☐	☐	☐	☐
Dislike slightly	☐	☐	☐	☐	☐	☐
Dislike moderately	☐	☐	☐	☐	☐	☐
Dislike a lot	☐	☐	☐	☐	☐	☐
Dislike extremely	☐	☐	☐	☐	☐	☐

Any comments?

Appendix 6 Results for liking and disliking; nine point hedonic scale of wooded wines

Date	Outlet	Consumer number	Gender	Age group	Kahikatea heavy 162	American oa 812	Totara light 633	Manuaka heavy 925	Radiata pine h 595	Control 364	Comments
21-Sep-06	Balmoral wines and spirits	1	2	2	7	8	9	8	4	7	
21-Sep-06	Balmoral wines and spirits	2	1	1	7	4	6	8	2	7	
21-Sep-06	Balmoral wines and spirits	3	2	2	7	6	6	6	7	7	
21-Sep-06	Balmoral wines and spirits	4	1	3	5	3	5	5	4	5	
21-Sep-06	Balmoral wines and spirits	5	1	2	4	2	5	5	6	3	
21-Sep-06	Balmoral wines and spirits	6	1	2	6	5	8	9	7	5	
21-Sep-06	Balmoral wines and spirits	7	1	2	4	3	6	5	5	5	
21-Sep-06	Balmoral wines and spirits	8	1	2	5	7	8	7	5	8	
21-Sep-06	Balmoral wines and spirits	9	1	2	7	3	4	3	7	7	
21-Sep-06	Balmoral wines and spirits	10	1	2	7	5	6	5	5	8	
21-Sep-06	Balmoral wines and spirits	11	1	3	7	6	9	8	5	7	
21-Sep-06	Balmoral wines and spirits	12	1	2	6	8	7	6	6	5	
21-Sep-06	Balmoral wines and spirits	13	1	2	1	5	6	6	3	8	
21-Sep-06	Balmoral wines and spirits	14	2	2	8	7	6	7	8	7	
21-Sep-06	Balmoral wines and spirits	15	2	2	6	6	7	3	7	5	
21-Sep-06	Balmoral wines and spirits	16	1	3	1	9	7	5	1	5	
21-Sep-06	Balmoral wines and spirits	17	1	1	6	8	9	7	8	8	
21-Sep-06	Balmoral wines and spirits	18	1	3	8	9	7	8	6	7	
21-Sep-06	Balmoral wines and spirits	19	1	3	8	7	7	8	7	8	
21-Sep-06	Balmoral wines and spirits	20	1	3	8	8	7	7	6	7	
21-Sep-06	Balmoral wines and spirits	21	2	1	8	6	7	4	3	7	
21-Sep-06	Balmoral wines and spirits	22	1	1	7	6	8	3	1	6	
21-Sep-06	Balmoral wines and spirits	23	1	1	8	5	4	8	7	6	
21-Sep-06	Balmoral wines and spirits	24	2	1	7	8	7	7	4	3	
21-Sep-06	Balmoral wines and spirits	25	1	1	4	6	7	4	4	7	
21-Sep-06	Balmoral wines and spirits	26	1	1	5	3	6	4	4	4	
21-Sep-06	Balmoral wines and spirits	27	2	2	7	7	8	8	4	7	
21-Sep-06	Balmoral wines and spirits	28	1	1	2	2	8	9	7	4	
21-Sep-06	Balmoral wines and spirits	29	1	1	7	7	7	7	7	7	
21-Sep-06	Balmoral wines and spirits	30	2	3	3	7	7	3	2	3	
22-Sep-06	Parkland's Liquor Centre	31	1	2	4	5	5	6	5	7	
22-Sep-06	Parkland's Liquor Centre	32	1	3	7	7	7	8	7	8	
22-Sep-06	Parkland's Liquor Centre	33	2	3	7	6	7	5	7	5	Very refreshing
22-Sep-06	Parkland's Liquor Centre	34	1	2	5	6	4	6	4	7	
22-Sep-06	Parkland's Liquor Centre	35	1	2	8	8	8	8	8	8	
22-Sep-06	Parkland's Liquor Centre	36	1	1	7	4	7	7	6	6	
22-Sep-06	Parkland's Liquor Centre	37	1	1	1	4	4	7	6	8	
22-Sep-06	Parkland's Liquor Centre	38	1	1	7	4	6	8	7	4	
22-Sep-06	Parkland's Liquor Centre	39	2	3	6	7	6	4	7	8	Good a palatibl
22-Sep-06	Parkland's Liquor Centre	40	2	2	8	8	7	4	7	6	
22-Sep-06	Parkland's Liquor Centre	41	1	1	4	5	5	6	4	7	
22-Sep-06	Parkland's Liquor Centre	42	2	1	8	7	5	1	8	7	
22-Sep-06	Parkland's Liquor Centre	43	1	1	6	4	6	6	6	5	
22-Sep-06	Parkland's Liquor Centre	44	1	1	7	6	6	8	2	2	
22-Sep-06	Parkland's Liquor Centre	45	1	1	8	8	6	5	7	7	
22-Sep-06	Parkland's Liquor Centre	46	1	1	5	3	5	5	7	6	
22-Sep-06	Parkland's Liquor Centre	47	2	1	7	3	3	7	6	6	
22-Sep-06	Parkland's Liquor Centre	48	1	2	6	5	8	8	7	7	
22-Sep-06	Parkland's Liquor Centre	49	1	2	3	3	6	6	6	7	
22-Sep-06	Parkland's Liquor Centre	50	1	3	2	4	6	6	2	7	Wines 633 and
22-Sep-06	Parkland's Liquor Centre	51	1	3	2	3	7	2	5	5	
22-Sep-06	Parkland's Liquor Centre	52	1	1	7	8	8	7	3	5	
22-Sep-06	Parkland's Liquor Centre	53	1	1	6	7	5	4	4	6	
22-Sep-06	Parkland's Liquor Centre	54	1	1	7	8	7	7	9	4	
22-Sep-06	Parkland's Liquor Centre	55	1	1	7	8	9	6	8	4	
22-Sep-06	Parkland's Liquor Centre	56	1	1	6	9	8	6	9	9	
22-Sep-06	Parkland's Liquor Centre	57	1	1	6	3	2	5	4	7	
22-Sep-06	Parkland's Liquor Centre	58	1	3	8	8	7	8	7	8	
22-Sep-06	Parkland's Liquor Centre	59	1	2	7	3	5	5	8	7	
22-Sep-06	Parkland's Liquor Centre	60	1	2	7	7	7	4	6	6	
27-Sep-06	The Village Winery,Mt.Eden	61	1	2	7	6	8	7	8	8	
28-Sep-06	The Village Winery,Mt.Eden	62	2	1	4	4	7	7	4	5	
28-Sep-06	The Village Winery,Mt.Eden	63	1	1	3	4	6	6	3	7	
28-Sep-06	The Village Winery,Mt.Eden	64	2	3	9	8	8	7	7	7	
28-Sep-06	The Village Winery,Mt.Eden	65	1	3	3	7	5	4	4	8	
28-Sep-06	The Village Winery,Mt.Eden	66	1	3	8	8	4	7	3	7	
28-Sep-06	The Village Winery,Mt.Eden	67	1	2	7	7	8	8	9	6	
28-Sep-06	The Village Winery,Mt.Eden	68	1	2	6	8	7	6	6	7	
28-Sep-06	The Village Winery,Mt.Eden	69	2	2	7	7	9	7	7	7	
28-Sep-06	The Village Winery,Mt.Eden	70	2	1	7	8	6	7	6	7	
28-Sep-06	The Village Winery,Mt.Eden	71	1	3	9	9	9	9	9	9	
28-Sep-06	The Village Winery,Mt.Eden	72	2	1	5	5	5	5	5	5	
28-Sep-06	The Village Winery,Mt.Eden	73	2	1	7	6	7	8	7	7	
28-Sep-06	The Village Winery,Mt.Eden	74	2	3	9	7	7	8	9	8	
28-Sep-06	The Village Winery,Mt.Eden	75	1	2	4	7	8	3	4	7	
28-Sep-06	The Village Winery,Mt.Eden	76	2	3	6	4	6	6	6	7	
28-Sep-06	The Village Winery,Mt.Eden	77	1	3	4	7	4	6	4	4	
28-Sep-06	The Village Winery,Mt.Eden	78	1	2	6	6	5	6	7	6	
28-Sep-06	The Village Winery,Mt.Eden	79	1	3	2	4	4	4	6	4	
28-Sep-06	The Village Winery,Mt.Eden	80	1	1	7	4	8	8	5	5	
28-Sep-06	The Village Winery,Mt.Eden	81	1	1	8	6	6	6	7	6	
28-Sep-06	The Village Winery,Mt.Eden	82	2	1	6	4	5	6	4	6	
28-Sep-06	The Village Winery,Mt.Eden	83	2	2	4	6	6	7	6	7	
28-Sep-06	The Village Winery,Mt.Eden	84	1	2	7	4	6	8	7	7	
28-Sep-06	The Village Winery,Mt.Eden	85	2	2	6	4	7	4	8	8	
28-Sep-06	The Village Winery,Mt.Eden	86	1	3	9	7	7	8	9	8	
28-Sep-06	The Village Winery,Mt.Eden	87	1	3	8	5	6	6	7	6	
28-Sep-06	The Village Winery,Mt.Eden	88	2	2	9	7	7	8	9	8	
28-Sep-06	The Village Winery,Mt.Eden	89	2	1	7	6	7	8	7	7	
28-Sep-06	The Village Winery,Mt.Eden	90	1	3	8	8	4	7	3	7	

Appendix 6 continued

29-Sep-06	The Thirsty Frog,Wines & Spirits	91	1	3	5	7	6	6	5	6	
29-Sep-06	The Thirsty Frog,Wines & Spirits	92	2	3	8	8	7	9	8	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	93	2	3	1	7	7	1	3	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	94	1	3	2	7	7	4	5	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	95	1	2	6	6	5	7	5	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	96	1	3	6	6	7	6	6	6	
29-Sep-06	The Thirsty Frog,Wines & Spirits	97	2	2	6	7	7	8	7	8	very similar in t
29-Sep-06	The Thirsty Frog,Wines & Spirits	98	1	1	7	2	4	6	2	5	
29-Sep-06	The Thirsty Frog,Wines & Spirits	99	1	3	6	8	8	7	8	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	100	2	2	6	8	8	8	7	6	
29-Sep-06	The Thirsty Frog,Wines & Spirits	101	1	3	8	9	9	7	7	8	
29-Sep-06	The Thirsty Frog,Wines & Spirits	102	1	3	1	1	8	6	1	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	103	1	2	1	1	5	3	2	3	
29-Sep-06	The Thirsty Frog,Wines & Spirits	104	1	2	3	1	6	2	2	5	
29-Sep-06	The Thirsty Frog,Wines & Spirits	105	2	2	6	7	6	8	6	5	
29-Sep-06	The Thirsty Frog,Wines & Spirits	106	1	3	4	3	6	7	2	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	107	2	3	4	7	8	9	6	8	Manuka heavy
29-Sep-06	The Thirsty Frog,Wines & Spirits	108	1	3	3	7	6	4	4	4	
29-Sep-06	The Thirsty Frog,Wines & Spirits	109	1	3	5	3	6	7	7	8	
29-Sep-06	The Thirsty Frog,Wines & Spirits	110	2	1	6	1	7	6	3	4	
29-Sep-06	The Thirsty Frog,Wines & Spirits	111	1	1	7	7	7	6	5	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	112	2	3	6	7	8	8	6	8	
29-Sep-06	The Thirsty Frog,Wines & Spirits	113	2	2	6	7	3	6	6	4	
29-Sep-06	The Thirsty Frog,Wines & Spirits	114	1	3	5	7	7	5	8	6	Radiata and toa
29-Sep-06	The Thirsty Frog,Wines & Spirits	115	2	1	8	5	6	8	8	8	
29-Sep-06	The Thirsty Frog,Wines & Spirits	116	2	2	4	6	7	4	6	4	
29-Sep-06	The Thirsty Frog,Wines & Spirits	117	2	3	5	7	6	7	6	5	
29-Sep-06	The Thirsty Frog,Wines & Spirits	118	1	1	9	8	7	6	1	8	
29-Sep-06	The Thirsty Frog,Wines & Spirits	119	1	1	7	4	7	6	7	7	
29-Sep-06	The Thirsty Frog,Wines & Spirits	120	1	1	8	2	5	3	7	6	
5-Oct-06	The Wine Vault,Grey Lynn	121	2	1	6	7	8	7	7	7	
5-Oct-06	The Wine Vault,Grey Lynn	122	1	3	7	6	5	6	6	5	
5-Oct-06	The Wine Vault,Grey Lynn	123	1	2	4	5	4	6	6	7	
5-Oct-06	The Wine Vault,Grey Lynn	124	1	2	1	3	2	7	4	5	good survey,Am
5-Oct-06	The Wine Vault,Grey Lynn	125	1	2	7	3	8	6	7	3	Kahikatea:nice
5-Oct-06	The Wine Vault,Grey Lynn	126	1	1	6	7	6	7	4	6	
5-Oct-06	The Wine Vault,Grey Lynn	127	1	2	7	6	6	4	7	7	
5-Oct-06	The Wine Vault,Grey Lynn	128	1	3	5	4	6	6	4	6	
5-Oct-06	The Wine Vault,Grey Lynn	129	1	3	3	7	9	4	6	8	
5-Oct-06	The Wine Vault,Grey Lynn	130	1	3	5	6	6	5	3	6	
5-Oct-06	The Wine Vault,Grey Lynn	131	1	2	5	7	8	6	5	8	
5-Oct-06	The Wine Vault,Grey Lynn	132	1	3	8	8	8	7	7	7	
5-Oct-06	The Wine Vault,Grey Lynn	133	1	3	6	7	8	8	8	8	
5-Oct-06	The Wine Vault,Grey Lynn	134	2	2	3	5	7	5	2	7	
5-Oct-06	The Wine Vault,Grey Lynn	135	1	2	2	7	2	4	2	3	
5-Oct-06	The Wine Vault,Grey Lynn	136	2	1	7	7	7	7	7	6	
5-Oct-06	The Wine Vault,Grey Lynn	137	1	2	5	7	8	6	5	8	
5-Oct-06	The Wine Vault,Grey Lynn	138	1	3	9	7	7	8	9	8	
5-Oct-06	The Wine Vault,Grey Lynn	139	1	1	7	2	2	4	6	5	
5-Oct-06	The Wine Vault,Grey Lynn	140	1	1	7	6	8	3	1	6	
5-Oct-06	The Wine Vault,Grey Lynn	141	1	2	7	6	8	7	7	8	
5-Oct-06	The Wine Vault,Grey Lynn	142	1	1	4	6	7	4	4	7	
5-Oct-06	The Wine Vault,Grey Lynn	143	1	3	2	4	6	6	6	7	
5-Oct-06	The Wine Vault,Grey Lynn	144	2	3	9	8	8	7	7	7	
5-Oct-06	The Wine Vault,Grey Lynn	145	1	3	1	9	7	5	1	5	
5-Oct-06	The Wine Vault,Grey Lynn	146	1	3	4	3	6	7	2	7	
5-Oct-06	The Wine Vault,Grey Lynn	147	2	1	8	2	5	3	7	6	
5-Oct-06	The Wine Vault,Grey Lynn	148	1	3	5	7	7	5	8	6	
5-Oct-06	The Wine Vault,Grey Lynn	149	2	2	6	8	8	7	8	7	
5-Oct-06	The Wine Vault,Grey Lynn	150	2	3	6	7	6	4	7	8	
6-Oct-06	Greenlane Liquor Centre	151	2	1	2	6	6	7	6	6	
6-Oct-06	Greenlane Liquor Centre	152	1	1	5	7	6	3	8	6	
6-Oct-06	Greenlane Liquor Centre	153	1	2	7	7	6	8	7	8	
6-Oct-06	Greenlane Liquor Centre	154	1	3	2	7	7	5	2	6	
6-Oct-06	Greenlane Liquor Centre	155	2	3	2	3	5	1	2	5	
6-Oct-06	Greenlane Liquor Centre	156	2	3	7	7	7	7	7	7	
6-Oct-06	Greenlane Liquor Centre	157	1	1	6	6	8	8	4	6	
6-Oct-06	Greenlane Liquor Centre	158	1	2	4	7	6	3	6	7	
6-Oct-06	Greenlane Liquor Centre	159	1	2	7	6	6	6	7	7	
6-Oct-06	Greenlane Liquor Centre	160	1	1	7	6	6	4	6	4	
6-Oct-06	Greenlane Liquor Centre	161	1	1	2	4	4	3	6	4	
6-Oct-06	Greenlane Liquor Centre	162	1	1	7	4	7	6	5	8	
6-Oct-06	Greenlane Liquor Centre	163	1	2	2	7	6	4	2	7	
6-Oct-06	Greenlane Liquor Centre	164	2	2	6	5	7	4	4	4	
6-Oct-06	Greenlane Liquor Centre	165	1	3	6	7	7	7	6	7	
6-Oct-06	Greenlane Liquor Centre	166	1	2	7	7	8	6	1	2	
6-Oct-06	Greenlane Liquor Centre	167	1	3	6	4	6	7	4	3	
6-Oct-06	Greenlane Liquor Centre	168	1	1	1	9	4	7	6	6	
6-Oct-06	Greenlane Liquor Centre	169	2	3	9	9	9	8	9	8	
6-Oct-06	Greenlane Liquor Centre	170	2	1	3	7	8	9	4	8	
6-Oct-06	Greenlane Liquor Centre	171	1	3	5	6	7	5	8	6	
6-Oct-06	Greenlane Liquor Centre	172	1	1	8	2	8	7	3	8	
6-Oct-06	Greenlane Liquor Centre	173	1	1	3	7	6	5	5	7	
6-Oct-06	Greenlane Liquor Centre	174	1	1	7	7	7	7	4	7	
6-Oct-06	Greenlane Liquor Centre	175	1	1	8	4	5	8	4	7	
6-Oct-06	Greenlane Liquor Centre	176	2	2	3	7	8	7	4	8	
6-Oct-06	Greenlane Liquor Centre	177	1	3	6	6	8	7	6	8	
6-Oct-06	Greenlane Liquor Centre	178	1	2	8	8	9	7	2	3	
6-Oct-06	Greenlane Liquor Centre	179	1	1	4	6	7	8	5	7	
6-Oct-06	Greenlane Liquor Centre	180	2	3	6	7	8	8	3	5	

Appendix 7 Photos of untoasted and toasted wood treatments in light and heavy conditions

American oak (untoasted)

American oak (light toast)

American oak (dark toast)

Cherry beech (untoasted)

Cherry beech (light toast)

Cherry beech (dark toast)

Rimu (untoasted)

Rimu (light toast)

Rimu (dark toast)

Kahikatea (untoasted)

Kahikatea (light toast)

Kahikatea (dark toast)

Silver beech (untoasted)

Silver beech (light toast)

Silver beech (dark toast)

Matai (untoasted)

Matai (light toast)

Matai (dark toast)

Radiata pine (untoasted)

Radiata pine (light toast)

Radiata pine (dark toast)

Manuka (untoasted)

Manuka (light toast)

Manuka (dark toast)

Totara (untoasted)

Totara (light toast)

Totara (dark toast)

Pohutukawa (untoasted)

Pohutukawa (light toast)

Pohutukawa (dark toast)

None remaining

Feijoa (light toast)

Feijoa (dark toast)

None remaining

Macrocarpa (light toast)

Macrocarpa (dark toast)

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