Sensory Profile & Consumer Acceptability of Sweet Cherries

By

Joseph Revell

Thesis submitted to the University of Nottingham for the degree of Masters of Research

Division of Food Sciences
School of Biosciences
University of Nottingham
Sutton Bonington Campus
Loughborough
Leicestershire
LE12 5RD

October 2008

Acknowledgements

First and foremost I would like to show my sincere gratitude and thanks to Dr Joanne Hort for her guidance and support and I would also like to thank Norton Folgate Ltd. particularly David Scott and Lesley Jones for their patience and support throughout this project. I would like to thank Ouahiba Guendouz, Anouska Hughes and Hannah Lacey who all helped me collect data, as 6 day periods to collect all this information would have been impossible if I had tried to do this alone. Finally I would like to thank my girlfriend Tess Jenkins, my family and friends primarily for their patience when I appeared to be on cloud 9 when my mind was on this project.

I would like to dedicate this work to Samuel Gaston a friend lost but not forgotten.

Abstract

The main objective of this study was to identify key drivers underlying consumer preference and acceptability of sweet cherries. This was achieved using a Flash Profile to identify the sensory diversity perceived providing sensory descriptions of a range of cherry varieties. Various preliminary experiments were performed to optimise the Flash Profile technique prior to the final experiment. In order to perform the final Flash Profile, six varieties of cherry were selected by Norton Folgate Ltd. and assessed by a panel of 12 assessors who all had sensory experience, but not with sweet cherry products. The Flash Profile results showed discrimination between the sweet cherries which was dominated by appearance, but texture and flavour appeared to have an influence. The same sweet cherry varieties were then put through a consumer preference test using a rank-rating method, where products were ranked in order of preference first, followed by a rating exercise to determine liking or disliking using the LAM scale. An internal preference map was generated using this data and this was extended by adding the Flash Profile and some analytical data to the map as supplementary data. The outcome was that Flavour intensity and juiciness appeared to be key factors behind preference and acceptability of sweet cherries.

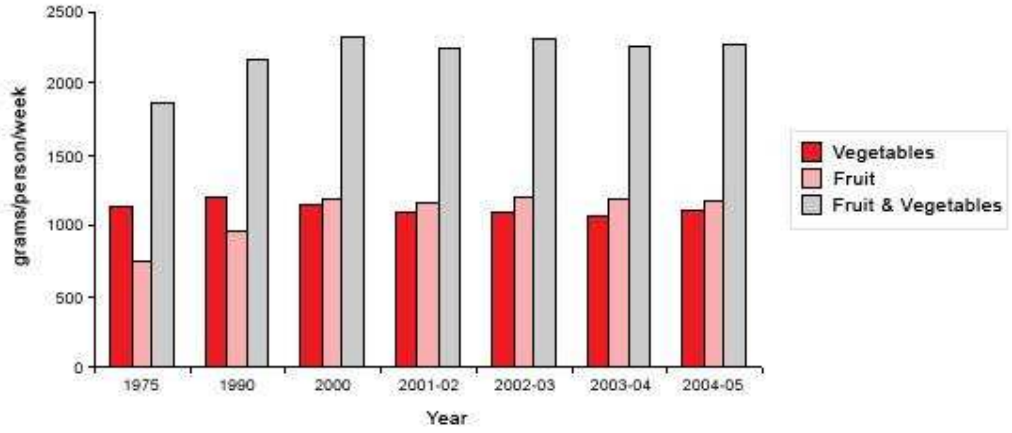
Contents

1. Introduction

1.1. Growing Cherry Market

Since the mid 1970's household consumption of fruit and vegetables has increased steadily, and over the last 10 years there has been an increase of approximately 10%, mainly due to a rise in fruit consumption, particularly bananas (DEFRA, 2004). Other factors such as government-led initiatives to promote consumption like '5-a-day' in the U.K. and 'Fruit & Veg – More Matters' in the U.S. may also have contributed to this rise. Figure 1.1 illustrates a rise in fruit purchase mirroring the trend seen in consumption. This highlights that fruits are commercially valuable crops especially in western society with its increasing demand for improved quality and extended variety of fruit available. The fruit industry is currently driven by a relatively small number of fruits, those of prime significance being banana, grape, citrus, top fruit (apples & pears) and tomato. However, western consumers are becoming more and more aware of select and exotic fruits, whose availability is often limited, and trade in this kind of fruit is increasing rapidly (Tucker, 1993).

Figure 1.1: Household purchases of fruit and vegetables in the U.K.



Source: Food & Grocery Information, Insight & Best Practice 2007

Stone fruits are one type of fruit becoming ever-more popular with western consumers and their global market is growing quickly, with global exports totalling more than $1billion in 2004, an 8% increase on that seen in the previous year. In terms of value, fresh cherry exports led the stone fruit category in 2004, totalling more than $393million followed by peaches & nectarines at $353million, plums $212million and apricots at $48million (FAS, 2005). Turkey is the leading global

producer of cherries with its production up 14% in 2004 to that of the previous year at a total of 400,000 tonnes. It is clear to see that the global cherry industry is extremely lucrative and that any research to improve cherry quality is viable and beneficial to the industry whether it is through agriculture and plant science or flavour, sensory and food science.

1.2. Origins of the Cherry

The sweet cherry is a direct descendant of the wild cherry, selected for human consumption and both were classified under the same name, *Prunus avium*. The sour cherry was also selected for human consumption but tends to be used in culinary and processed products and it too descends from the wild cherry but differs greatly in taste and is considered to be a separate species, *Prunus cerasus.*

The wild cherry is a species of cherry, native to Europe, northwest Africa, western Asia, from the British Isles south to Morocco and Tunisia, and east to southern Sweden, Poland, Ukraine, the Caucasus, and northern Iran (Anon., 2006). The origins of the sweet cherry however remain somewhat of a mystery but it is understood that they came from the Caucasus in what would be modern day Armenia.

Figure 1.2: The Caucasus Mountains and the likely location of *Prunus avium*'s origin.

Source: www.weecheng.com

There are reports of its deliberate cultivation in Turkey and soon after in Greece by 800 BC but its introduction to the rest of Europe was first recorded by an ancient Roman scientist/historian by the name of Pliny, author of Naturalis Historia (Natural History). He goes so far as to say that before the Roman consul Lucius Licinius Lucullus defeated Mithridates in 74 BC, Cerasia ... non fuere in Italia, "There were no cherry trees in Italy". According to him, Lucullus brought them in from Pontus – an area covering the south west coast of the Black Sea which fits with the theory of originating in the Caucasus - and in the 120 years since that time they had spread across Europe to Britain. This likely region of sweet cherry origin can be seen above in Fig. 1.2.

1.3. Sweet Cherry Varieties

It is thought there are several hundred varieties of sweet cherry grown commercially world-wide but most of these are simply cultivated and marketed locally. Only a select few of these several hundred varieties are suitable for wide-scale production and sale on the global market, due to their quality attributes matching market and grower requirements (Dodd, 1998). Like most fresh products it is predominantly 'market' rather than 'grower' requirements which drive commercial selection with growers adhering primarily to the market requirements before outlining requirements of their own. The market requirements influencing commercial variety selection include, season (availability), fruit size, fruit colour and fruit firmness. The grower must satisfy the market requirements above before taking into account their own requirements of precocity, productivity, susceptibility to pests & disease and susceptibility to rain-induced cracking (Dodd, 1998).

In an ideal world cherries would be in season somewhere in the world all year-round, however, this is not the case. Relative to other fruits, cherries have a short, intense fruiting season where-by different varieties mature ready for harvesting at different times. The varieties can be categorised by this trait as either early, mid or late season cherries. This makes it extremely important that a variety from each category is cultivated in order not to limit or restrict the length of the season in a particular region. Fruit size is an important factor in consumer liking and acceptance as bigger fruits are generally considered to be more attractive to the eye and therefore sell more easily and usually at a higher price per gram, so varieties yielding larger

fruits will be preferred commercially. Similarly to that of size, colour has an essential role in appearance as consumers regardless of their age, gender or ethnicity prefer darker coloured varieties (Crisosto, *et al.*, 2003). Finally, the other key attribute is fruit firmness, growers/exporters/outlets find them much easier to handle, store and transport plus they tend to have a longer shelf-life than softer varieties. That does not mean that there is no place for softer varieties, it is just that their market resides locally to the region in which they are grown as they do not travel very well. The Italians categorise sweet cherries on this basis with the soft flesh varieties described as tenerine and those with firm flesh as duroni (Bargioni, 1996).

A factor which growers must be particularly aware of is precocity, as all plants have an initial immature/junior vegetative phase after planting where they must establish themselves as adults before they are able to flower and subsequently produce fruit. This was typically 7-10 years with some of the older varieties being used, however recently introduced varieties coupled with recently developed dwarfing root stocks have seen trees begin to produce fruit as early as 3 or 4 years from planting (Dodd, 1998). This is extremely important to the grower in terms of economic viability as the grower must be able to sustain the necessary input without any financial return for the first few years. Another big factor, and probably the most obvious one to the grower, is production. In terms of economic return, growers will maximise profits by using varieties that crop consistently and heavily, but they must be cautious of over-cropping as this may lead to irregular cropping. Varieties that are pest and/or disease resistant are preferred both by the grower and the market, as consumers would rather have pesticide-free produce where possible, and growers would rather not spend copious amounts of money on pesticides if they can avoid their use. Cracking is a common problem with all cherries and in regions where rain during the pre-harvest period is frequent, growers will select varieties with a reduced susceptibility to rain-induced cracking.

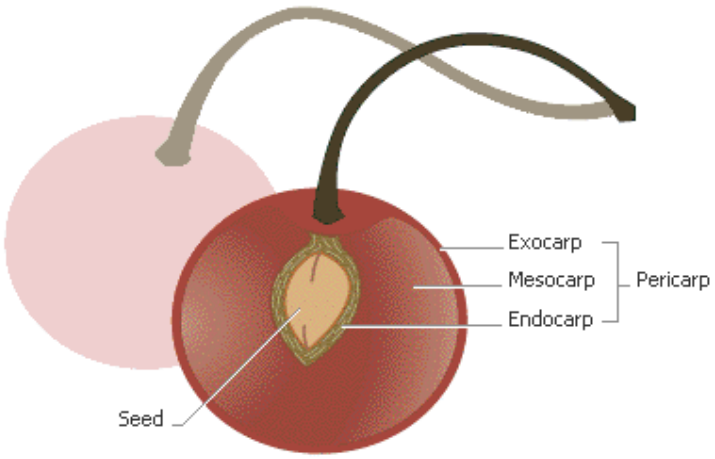
Some common commercial varieties that are grown in the largest cherry producing countries and are highly or partially suited to the requirements above include Bing, Burlat, Hedelfinger, Moreau, Napoleon and Van to name but a few. Bing is arguably the most popular variety with global exports higher than any other and Burlat which is also an important variety as it crops heavily and ripens early, extending the start of the northern hemisphere season (Bargioni, 1996). Other

varieties are more limited in commercial distribution and are produced solely by one country; some examples include Reverchon in France, Turfanda in Turkey and Ambrunés in Spain. These sweet cherry cultivars must all share common structural characteristics that make them cherries but they also have many differences in biochemical composition, and it is these differences that give rise to variations in flavour and other sensory attributes. For example how a cherry tastes could be directly related to a specific compound and its concentration within a fruit - a compositional attribute - so it is essential to analyze composition as well as perception to truly understand what factors influence its variation. Different concentrations of compositional attributes possibly coupled with any cultivar specific compounds may give rise to the variations in flavour release and sensory perception.

1.4. Cherry Composition

Morphologically all cherries share common features distinguishing them as cherries, these include the seed surrounded by the pericarp and a stalk providing nutrients via vascular components from the plant as the fruit grows, matures and ripens on the tree. All cultivars share the characteristics displayed in Figure 1.3.

Figure 1.3: The basic cherry structure in its simplest form.



Source: MSN Encarta : Fruit; Cherry.

The pericarp can be split into 3 components, the endocarp simply covers the seed forming part of the stone; the mesocarp provides the most desirable edible constituent of the cherry and is therefore arguably the most important; but then the exocarp or skin can be considered equally as important as it dictates the appearance

which will be the initial factor in consumers choosing ‘to buy’ or ‘not to buy’ plus it may also affect texture on first bite.

There are many factors which determine fruit composition: where it was planted, how it was grown, when it was harvested, how it ripens, and so on. These areas require further expansion and discussion in order to understand the true nature and scale of variation in fruit composition and ultimately flavour and sensory perception, plus it also highlights why it is extremely difficult to acquire uniform fruit for experimental exercises.

1.4.1. Physical Factors

There are many physical factors that can affect composition, they can be categorised as either climate or soil factors and should be considered carefully when selecting a suitable site for cherry cropping. Climate factors include temperature, rainfall, wind, light quality and photoperiod. Soil factors include soil type, depth, drainage, pH and nutrient status. There are also soil issues when replanting in soils previously used for growing cherries or other stone fruits, where-by the new trees display signs of poor establishment, growth and cropping (Longstroth & Perry, 1996). The causes of such problems may be due to nematodes, soil fungi, residues of toxic minerals or other, often unidentified, causes. So the advice given to growers is to avoid replant sites as these problems can persist over a few decades, the only alternative to this is to sterilise the soil using chemical sterilants, but these are often detrimental to the environment and reduce profit margins through additional costs. All the factors above vary widely by the region in which they are grown, which is why it is important, not just for traceability, that the fruit market labels fruits with country of origin as well as variety. Variation of fruit occurs within countries of origin, ‘Van’ cherries from California are likely to have different composition and sensory attributes to that of ‘Van’ cultivated in Oregon even though the country of origin is labelled U.S.A. for both.

1.4.2. Physiological Factors

Variation occurs not just between regions but at an intra-region level, with variation of cherry composition on a single tree. The best quality fruit grows from the outside of the tree canopy up to approximately 1m in, regardless of tree size, so

smaller trees are favoured to minimise inferior fruit production. The reason for better quality fruit towards the outside of the canopy is related to sunlight, as ripening cherries are active sinks for the products of photosynthesis (Gucci *et al.*, 1991). Photosynthetic rate is higher towards the outside of the canopy as the quality of light is much more intense which in turn fixes more carbon in these leaves allowing more sugar to accumulate in these cherries opposed to those well within the canopy with restricted light.

Two key physiological factors related to composition are maturation and ripening, and it is the changes in composition during these processes that will define quality recognized by those in the industry and the consumer. The ripening of sweet cherries and their rapid increase in size and weight occurs simultaneously during the last few weeks prior to harvest (Table 1.1).

Table 1.1: The relationship between fruit growth, softening and sugar accumulation prior to commercial maturity in Royal Anne sweet cherries cultivated at Corvallis, Oregon, 1991.

Source: Adapted from Barret & Gonzalez, 1994

Weeks before commercial maturity	Mean fruit weight (g)	Flesh Firmness (g)	Soluble Solid Content (%)
4	4.8	>2000	5.2
3	6.9	1691	8.4
2	(8.9)*	675	9
1	10.5	506	10.6
0	12.3	301	14.3

*Estimated

Up to 25% of the final fruit weight is amassed in the last week prior to harvest and during this time there are distinct changes in fruit colour, flavour and texture. Fruits become much sweeter during ripening as sugar concentrations increase while acids, predominantly malic acid, remain relatively constant (Spayd *et al.*, 1986). This growth and sugar accumulation would suggest it would be better to delay harvesting to obtain fruit with the best yield and taste, but flesh firmness declines during ripening resulting in the choice of harvest date being a compromise between these factors.

With cherries being a 'non-climacteric' fruit (Hartmann *et al.*, 1987), the accumulation of sugar will cease upon harvesting and the flavour will not develop any further. This highlights why the date of harvest is so critical to the quality of cherry fruits, too early and the fruit is small and bland, too late and the fruit becomes soft and difficult to handle during transport and storage.

1.4.3. Optimum Composition

It is clear from the evidence above that what determines composition is an array of factors, some of which are minimal and others critical to the final quality of the product. An ideal composition would include a high sugar content balanced with malic acid and key aroma volatiles such as benzaldehyde, *E*-2-hexenal and hexanal to develop a desired flavour (Mattheis *et al.*, 1992a; Mattheis *et al.*, 1992b). Colour and texture are also just as important as flavour in providing optimum composition for the consumer market. As mentioned earlier Crisosto, *et al.* (2003) highlighted consumer preference to darker cherries and this colour is directly related to anthocyanin accumulation and this is the most commonly used indicator of ripeness (Looney *et al.*. 1996). There is a maximum level of anthocyanin content as it accumulates through the colour stages from pale straw to very light red, red and finally mahogany. Following this the red/black colours begin to brighten as anthocyanin synthesis retards until it starts to break down and this is illustrated when the cherry passes optimum maturity, initiating the formation of brown shades. Firmness is a key attribute to ensuring optimum quality and the market perception is that the best cherries are firm overall and the flesh is crisp (Looney *et al.* 1996). The enzymes responsible for these textural changes during ripening and maturation are pectin methyl-esterase (PME), polygalacturonase (PG) and β-galactosidase (β-Gal) (Barrett & Gonzalez, 1994). Reports have shown that PME and PG work together in softening by increasing solubilisation of the cell walls. It is believed that PME is needed to liberate cell wall galacturonans through de-esterification before enabling PG to hydrolyze these galacturonans. The role of β-galactosidase is unclear as the exact mechanism is still an area of speculation but Barrett & Gonzalez reported a sharp increase relatively later than PME and PG and continued softening was correlated to this. This suggests β-galactosidase is involved but its significance requires more consideration.

1.5. Cherry Flavour

Flavour results from the combination of two sensory perceptions, to taste and to smell. Humans can detect five distinguishable tastes on the tongue, four familiar tastes being sweet, sour, bitter and salt, with the fifth less popular term known as

umami. Umami is a term originating from the orient (Ikeda, 1909) which roughly translates into English as 'savouriness', however it was widely considered to be a flavour not a taste by the western world. This was until the 2nd International Symposium on Umami taste took place in Sicily, 1990, where it was widely accepted by the majority of scientists as the fifth basic taste. Sugars and organic acids are the primary constituents contributing to taste of fruits but the bitter nature of some fruit can be attributed to its isocumarin content. Our identification of the characteristic flavour of individual fruits is largely derived from our perception of smell and is due to the production of specific aroma volatiles. It is therefore believed that the flavour of fruit derives from these constituents and others displayed in Table 1.2.

These flavour attributes are not exclusive of each other, there are complex interactions between the constituents such as sugars, organic acids, phenolics and more specialized flavour compounds, including an extensive range of aroma volatiles (Tucker, 1993). These compounds are present at a variety of concentrations in cherries and this appears to be the primary factor giving rise to flavour differences between the individual fruits and each cultivar (Bernalte, *et al.* 1999).

Table 1.2: The relationship of composition versus flavour.

Flavour attribute	Constituents
Sweetness	Sugars
Sourness	Acids
Astringency	Phenolics, tannins
Bitterness	Isocumarins
Aroma	Odour-active volatiles
Off-flavours	Acetaldehyde, ethanol, ethyl acetate
Off-odours	Sulphurous compounds

1.5.1. Sugars & Acids (Non-volatiles)

Sugars and organic acids are key respiratory substrates in cherries but they are present in larger quantities than simply that required for involvement in energy generation. Fruits differ in their relative contents of sugars and organic acids (Ulrich, 1970; Whiting, 1970) with the most prevalent sugars in cherries being fructose and glucose combined with relatively small quantities of sucrose and the most common organic acid being malate (M^{c}Cance & Widdowson, 2002). Other non-volatile minor constituents present in cherries include sorbitol and mannitol (sugar alcohols) plus ascorbic, citric, succinic and fumaric acids (Girard & Kopp, 1998).

Sugars and organic acids are photosynthetic assimilates that accumulate during development where-by cells begin to expand as these assimilates, provided by the rest of the plant, are deposited within them, usually in plastids and the vacuole. Some fruit accumulate the bulk of their carbohydrate prior to the on-set of ripening and this is either stored as starch, or more predominantly as sugar in this case. Cherries continue to accumulate sugar from the plant during ripening and in cherries this accounts for the vast majority of the intensity of their flavour. Cherries are dependent on the plant for assimilates during ripening and they fail to develop full flavour if harvested too early and are therefore considered commercially unacceptable if not 'vine ripened'. This is because they are unable to accumulate quantities of sugar and acid that will enhance taste to the levels desired by consumers. It is also important that the acquisition of both is balanced particularly in fruits because too much of one without the other could be undesired and the relationship of this balance can be seen in Table1.3.

Table 1.3: The relationship of sugar/acid ratio versus flavour.

	Sugar	
Acids	High	Low
Moderate to high	Best flavour combination	Sour, tart
Low	Sweet	Insipid, tasteless

1.5.2. Volatiles

Flavour compounds in cherries can be complex but the vast majority are relatively simple molecules which, being volatile, account for the fruit's odour and aroma. Odour and aroma should not be confused with each other, as they are often considered to be the same thing. The term odour is more appropriate in describing the smell of food prior to consumption and this is recognised as orthonasal perception, whereas aroma is the smell of food as it is being consumed in the mouth and is recognised as retronasal perception.

These 'flavour volatiles' responsible for odour and aroma are present at relatively low levels and are often expressed in terms of quantity as ppm, but they are extremely important in providing the characteristic flavour which distinguishes them as cherries from other fruits as other fruits share similar tastes due to corresponding sugar (fructose/glucose) and acid (malate) composites. The flavour profile of sweet cherry is quite complex; for example, headspace analysis of volatiles coupled with GC-MS indentified at least 60 different compounds in sweet cherry (Bernalte, *et al.* 1999) and in other fruit it is even more complex with at least 230 and 330 compounds in apple and orange respectively (Van Straten, 1977). Also the nature of the volatiles involved varies and sweet cherries have been reported to include aldehydes, alcohols, alkanes, esters, aromatic hydrocarbons and acetic acid to name but a few (Schmid & Grosch1982a ; Mattheis, *et al.* 1992a; Mattheis, *et al.* 1992b; Mattheis, *et al.* 1997; Bernalte, *et al.* 1999; Girard & Kopp, 2002). Of these compounds three have been identified from processed sweet cherry products as important contributors to sweet cherry aroma and flavour, benzaldehyde, hexanal, *E*-2-hexenal (Schmid & Grosch, 1986b). It has been presumed by others (Bernalte, *et al.* 1999; Mattheis, *et al.* 1992a; Mattheis, *et al.* 1992b; Mattheis, *et al.* 1997) that these three compounds from processed products are equally as important to their fresh fruit counterparts. Another volatile reported to influence cherry flavour is *E*-2-hexen-1-ol which in some varieties is the most abundant volatile compound (Girard & Kopp 1998). The C_6 aldehydes are produced from enzymatic reactions but their relative quantities within the fruit are not associated to the specific enzymes ability to convert them; it is attributed to the quantities of the precursor molecules already present that give rise to them (Mattheis, *et al.* 1997). For example the C_6 molecules hexanal and *E*-2-hexenal are products of fatty acid oxidation or more specifically the oxidation of linoleic and linolenic acids in the presence of lipoxygenase; *E*-2-hexen-1-ol is a corresponding secondary compound from these oxidation reactions (Drawert et al., 1996; Paillard & Rouri, 1984). It has been reported that quantitative differences of hexanal and *E*-2-hexenal in cherries is not due to differences in lipoxygenase activity rather they are related to the initial quantity present of the precursors, linoleic and linolenic acids (Bernalte, *et al.* 1999). Similarly benzaldehyde is produced from hydrolysis of amygdalin contained in cherry pits (Nahrstedt, 1972) and its quantity within the fruit is associated with the quantities of amygdalin present prior to enzyme activity.

1.5.3. The Significance of Flavour to Sensory Perception

The literature explaining how these flavour composites (volatiles and non-volatiles) affect sensory perception (particularly sweetness) and acceptance is contradictory. Regarding flavour, Crisosto *et al.*, (2003) reported that acceptance was driven by soluble solids content and that titratable acidity did not play a role in consumer acceptance. It seems logical that consumers would prefer sweeter cherries and find them more acceptable but Guyer *et al.*, (1993) found that it was not just sweetness driving acceptability. They reported that sensory perceptions of flavour and sweetness along with Brix/acid ratio and titratable acidity did have a role to play in acceptability. Both agreed that colour also has a role to play in acceptability but the focus here, is on flavour.

The perception of sweetness appears to be an important factor in acceptability and preference and Guyer *et al.*, (1993) reported the perception of sweetness was dictated by Brix/acid ratio not just Brix alone. They found that as the Brix/acid ratio increased, consumer perception of sweetness does likewise. They reported a significant correlation between Brix/acid ratio and sweetness perception. The changes they observed in Brix/acid ratio were as a result of different harvest times of a group of cherry varieties. Both the sugar and acid contents within the fruits increased the later they were harvested but the increases in sugar content were greater than that of total acidity. Bernalte *et al.*, (1998) had evidence contradictory to Guyer *et al.*, (1993). They found the opposite, when they compared two Spanish sweet cherry varieties, Ambrunes and Pico Colorado. Ambrunes had a lower Brix/acid ratio and also a lower Brix than Pico Colorado yet their panellists perceived Ambrunes to be sweeter and have a greater 'sweet cherry taste'. Bernalte *et al.*, (1993) had undertaken volatile analysis which showed Ambrunes to contain higher levels of key volatiles, hexanal and (*E*)-2-hexenal, resulting in a more aromatic cherry. It could be that the perception of Ambrunes being sweeter than Pico Colorado is due to a taste-aroma interaction where the sweetness of Ambrunes is enhanced by its stronger aroma (Noble, 1996).

These reports suggest that sweetness could be a key factor and one of the drivers of consumer preference and acceptability. It also debates what is responsible for perception of sweetness. It would therefore be appropriate, where possible, to undertake some flavour analysis experiments to see if this additional information can aid explanation of the sensory perceptions of sweet cherries and what the drivers are behind consumer preference and acceptability of this type of product.

1.5.4. Flavour Analysis Techniques

Volatile and non-volatile data may aid understanding of the various flavour perceptions that may arise from sensory analysis and these flavour perceptions could play an important role in consumer preference and acceptability.

1.5.4.1. Non Volatile analysis

The key non-volatiles responsible for cherry taste were outlined in Chapter 1.4.1 as sugar, more specifically fructose and glucose and acid particularly malate. HPLC analysis could be applied to the cherry samples, but this will be time-consuming and there is only 6 days (shelf-life of the cherries) in which to undertake all analyses from including sensory and volatiles analysis. In order to keep this non-volatile analysis simple, only the common commercial fruit quality analyses will be used to determine the key non-volatile profiles of the cherry samples.

These include:

- °Brix (refractive index)
- Total Acidity
- pH

Adolph Ferdinand Wenzeslaus Brix defined the Brix scale as the measurement of the dissolved sugar-to-water mass ratio of a liquid. It was originally measured with a saccharimeter which measures specific gravity of a liquid but refractometers are now preferred, particularly in the fruit industry, due to their ease of use and portability. Using a refractometer involves passing light through a thin film of fruit juice and the degree to which the light is refracted (deflected from its straight line path through the samples) is compared to the measurement in distilled water and expressed as an empirical, non-linear parameter, °Brix. A 25°Brix solution is a solution that comprises of approximately 25% sugar (sucrose), with 25 grams of sugar per 100 grams of solution. Or, to put it another way, there are 25 grams of sucrose sugar and 75 grams of water in the 100 grams of solution. Refractometers used in the raw fruit industry range from 0-50°Brix as the juice from raw fruit products rarely exceeds 30°Brix however, areas of the food industry that use processed fruit products such as purées and concentrates often use refractometers that can measure beyond 50°Brix.

Total acidity (TA) or sometimes referred to as titratable acidity involves taking a measured volume of cherry juice and running a simple titration using a hydroxide compound to neutralise the acid in the juice. This can then be used to calculate how much malic acid was present in the sample and this expressed as a percentage of total acidity or as % malic acid.

pH is used to determine the concentration of hydrogen ions in a solution and hence the relative acidity of the cherry samples once the juice has been pressed from the fruit. This is achieved by placing a pH meter (consisting of two electrodes) into a cherry juice sample where it then measures the activity of hydrogen ions (H+).

1.5.4.2. Volatile Analysis using Gas Chromatography – Mass Spectrometry (GC-MS)

GC-MS analysis requires extraction of the aroma volatiles from cherries in order to create a sample that will be compatible with the instrument itself. Two options are commonly used to extract volatiles from a sample, solvent extraction and solid phase micro extraction (SPME). The type of solvent used depends on the polarity of the volatiles desired for analysis. Polar volatiles require a polar solvent such as methanol, whereas non-polar volatiles require an organic solvent, either dichloromethane (DCM) or hexane would be appropriate. Considering the key volatile compounds of cherry flavour described in Chapter 1.4.2 it would be best to use a non-polar solvent to appropriately extract the volatiles, but the cherry samples must be homogenised first in the presence of water to create a slurry that is not too viscous allowing the solvent to mix through the sample. The presence of $CaCl_2$ in the mix and an internal standard will also be required. The $CaCl_2$ reduces enzyme activity which may degrade some of the volatile compounds and therefore alter the final profile. A known (or quantified) internal standard is required to enable quantification of the other compounds, as the areas of the various peaks generated by the various volatiles in the sample will be compared to the peak area of the known internal standard. This will leave the polar compounds such as acids and sugars in the water phase and the volatiles can be extracted from the hexane layer that will settle on top of the solution. The sample may require centrifugation to separate the polar from the non-polar into layers or the sample may take a long time to separate. The hexane layer can then be skimmed from the top of the solution forming a volatile extract sample compatible for GC-MS analysis.

A relatively small quantity (1µl) of the volatile-rich hexane layer can then be injected into the GC-MS via a hot region which will volatilise the liquid into a gas phase. This gas composed of various volatiles is then swept on to the GC column by a carrier gas (typically helium). The column is initially cool and the volatile compounds deposit themselves on the column wall. The column wall is lined with a gum to which they dissolve. Increasing the temperature of the column causes the compounds to leave the gum lining and enter the carrier gas flowing through the column and it is the compounds with the lowest boiling points that pass through the column first. This separates the aroma volatiles prior to ionisation and detection in the MS.

1.6. Sensory Characteristics of Cherries

Previous studies into the sensory characteristics of cherries have generated and identified many sensory attributes perceived by assessors, all of which are related to visual, olfactory, gustatory and tactile/kinaesthetic sensory perceptions. Basic sensory attributes include appearance, odour, flavour, texture and feel. These give rise to more specific sensory descriptions and the order in which these basic attributes are typically perceived in fruits is as follows:

- Appearance
- Odour
- Texture
- Flavour (aromatics, chemical feelings, taste)

The basic attributes are not exclusive of each other, quite often most if not all of these attributes overlap as the subject receives an almost simultaneous array of sensory impressions. This makes it difficult for him or her to provide an independent evaluation of each attribute but this difficulty of independent evaluation can be eased through sensory training. These sensory perceptions, often described as attributes, form the basis of people's judgement to like or dislike a fruit depending on each attribute in relation to each person's level of expectation.

1.6.1. Appearance

Appearance is essential as it is often the initial sensory attribute that can determine a consumer's decision to purchase a product or not as the case may be. There are three important characteristics associated with the appearance of fruit, colour, size & shape and surface texture. These are the only characteristics a consumer can use as indicators of cherry quality or ripeness as the two are closely related prior to purchase.

1.6.1.1. Colour

This is an important attribute in consumer acceptance as there is a preference for dark red colour cherries (Crisosto *et al.*, 2002; Crisosto *et al.*, 2003). This colour is associated with cherries that are ripe and 'ready to eat' whereas paler shades of red may be tolerable but less desirable. In contrast the lack of uniformity or presence of any blotchy yellow spots would indicate poor quality as it suggests these cherries may not have been on the tree long enough to mature to a satisfactory level, particularly at the beginning of the season when growers try to stretch the seasons limits. Other colours are important besides the Red/Yellow indicating ripeness, browning often occurs when cherries have progressed beyond optimum eating quality. Previous studies have measured attributes that focus on colour intensity and uniformity (Kappel *et al.* 1996).

1.6.1.2. Size & Shape

Size is factor, with bigger fruits taking preference as they are thought to be more appealing to the eye and are perceived to be of a higher quality than their smaller counterparts (Vittrup Christensen, 1995) but an optimum size, based on average weight, was reported at between 11-12g (Kappel *et al.* 1996). Cherries have a characterised shape of being round and anything contrary to this would be perceived as a defect.

1.6.1.3. Surface Texture

Surface texture of cherries can give a good forewarning of two common defects associated with cherries, 'cracking' in the pit region where the pericarp has

split because its development during maturation is unable to match the rapid growth seen in the mesocarp (Brady, 1987), the other defect being cherries' susceptibility to bruising as they soften in storage (Crisosto *et al*, 1993).

1.6.2. Odour

Volatiles associated with the odour of whole unprocessed cherries do not have a significant role in a consumer's judgement of good quality as it is very rare that you see someone in the supermarket attempting to smell fruits on the shelf. However it can certainly give a good indication of bad quality as internal decay can sometimes be masked by a sound external appearance, but if a fermentative taint is being emitted, the consumer is likely to avoid it. Compounds typically related to internal decay of cherries, which often give rise to "off" odours and tastes include the formation of acetaldehyde and ethanol directly from fermentative decay, plus methanol formation from pectolytic decay of the cell wall (Esti *et al.*, 2002).

1.6.3. Texture

Texture is complex and it can be perceived in two ways, reaction to stress, and properties associated with feel. Reaction to stress is measured as a mechanical property, such as fruit firmness using the kinaesthetic sense in the muscles. Fruit firmness is an important sensory attribute that is always reported in previous studies of sensory attributes of cherries (Dever et al., 1996; Kappel et al., 1996; Bernalte 1999). Firmness is often a problem area in terms of quality with cherries as they soften much more quickly than desired. There is also a compromise for the grower between flavour and softness, because if picked too early full flavour will not have developed but if picked too late they may be too soft for the transfer around the global market. The principal tactile property of sweet cherries on observation of previous studies is juiciness and the juicier they are the greater the liking (Dever *et al.*, 1996; Bernalte *et al.*, 1999). As mentioned earlier the enzymes associated with their softening include PME, PG and β-Gal with the first two arguably the most significant.

1.6.4. Flavour

As mentioned earlier in the chapter 1.5, flavour is a combination of both taste and retronasal perception. Previous studies observing the flavour of cherries appear to attribute flavour to common terms of sweetness, sourness, sweet cherry or cherry flavour. (Guyer *et al.,* 1993; Dever *et al.*, 1996; Kappel *et al.*, 1996; Bernalte *et al.*, 1999; Esti *et al.*, 2002).

1.6.5. Noise

Noise is often produced when a product such as cherry is being consumed and although it is only minor it should not be ignored. Particularly in fruit sound or noise is often closely associated with the quality of texture, such as crunchy and crisp contributing to the perception of freshness.

1.7. Sensory Techniques

Sensory techniques and tests vary in their complexity, objectives and outcomes, but in general they can be placed into one of three categories; discrimination, descriptive or consumer tests. In brief discrimination tests determine whether a difference exists between products, descriptive tests assess how they may differ and consumer tests determine whether products are appropriate and acceptable to the general public as a whole or a target population.

1.7.1. Discrimination Tests

Put simply discrimination tests are used to establish if a sensory difference exists between two or more similar products. These tests can be used to determine whether there is an overall difference or a specific attribute difference between the products. Popular discrimination test methods include the 'Triangle Test (ISO 4120:2004)', 'Paired Comparison (ISO 5495:2005)' and 'Duo-Trio Test (ISO 10399:2004)' to name but a select few. In some respects discrimination tests represent the most useful analytical tools available to the sensory professional, because on the basis of a perceived difference between two products one could then justify proceeding to a descriptive test to identify the basis for the difference (Stone & Sidel,

2004). Discrimination tests are particularly useful if a food manufacturer changes an ingredient or production process of a specific product and they want to know if there is a significant overall difference observed in the final product. The desired outcome of discrimination tests is not always to seek a difference. For example, a crisp manufacturer may want to reduce the salt added to their crisps due to media and government pressures. Yet they will not want to compromise flavour and so the desired outcome of testing the new reduced salt product to the original would be to hope that no significant difference is observed. The opposite of this scenario would be that a food manufacturer has improved their recipe and they are looking for a significant difference. Discrimination/difference tests are limited to only one of two outcomes 'Yes, there is a significant difference' or 'No, there is no significant difference' between the products. These tests are unable to determine how the products may be different or the magnitude of any differences, descriptive tests however are able to indicate where differences exist and with the use of various scales these differences may be quantified.

1.7.2. Quantifying Sensory Responses

In brief quantifying sensory responses involves psychophysics, the study of relationships between sensory stimulus and the human response. Quantifying responses requires the use of a scale and the type of scale used depends on the objective of the test and the time and resources available. The use of appropriate scales will provide a measure of the difference in a sensory property between samples enabling descriptive and inferential statistics to be obtained. These statistics will then provide a rationale for decisions about the products being assessed and the judges who participated in the assessment (Stone & Sidel, 2004).

Currently there are at least four types of scale commonly used in sensory evaluation techniques. These include:

1. **Nominal** scales – naming and classification of samples
2. **Ordinal** scales – ordering and ranking of samples
3. **Interval** scales – measuring magnitudes of difference between samples assuming equal distances between points on the scale.
4. **Ratio** scales – measuring magnitudes of difference assuming equality of ratios between points on the scale.

Nominal scales require categorising or classifying items, for example:

'Which type of fruits do you consider to be sweet? Check as many as appropriate'

A) ***apple*** **B)** ***orange*** **C)** ***pears*** **D)** ***bananas***

E) ***grapes*** **F)** ***Mango*** **G)** ***cherry*** **H)** ***other***

All or none of the groups could be checked in this type of test but the categories do not represent any particular order or quantitative relationship. A classic example is the numbers carried by football players (Meilgaard *et al*. 2006).

Ordinal data is similar to nominal data in that a panellist will place assessed items into groups but in this case the groups belong to an ordered series, for example:

'How sweet are these cherries?'

A) ***not sweet at all*** **B)** ***slightly sweet*** **C)** ***moderately sweet***

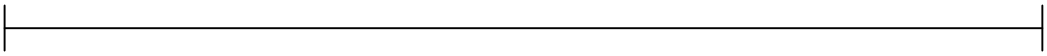
D) ***sweet*** **E)** ***very sweet***

The categories in an ordinal scale are not interchangeable like those observed using nominal scales. No assumptions should be made regarding the distance between categories or the magnitude of the attribute (sweetness) represented by a category. The data gathered from tests using ordinal scales is non-parametric and so too is that obtained from tests using nominal scales however, ordinal scales have more in common with magnitude scales than with nominal scales. Any statistical differences seen in products assessed using ordinal and/or nominal scales are calculated using a Friedman test then a Least Significant Ranked Difference (LSRD) test is applied to determine where the difference is i.e. which samples are significantly different to each other. As all that can be assumed from ordinal scales is that one category is either greater or less than another category, these scales often provide the first and most basic scales for measuring perceived intensities, in this case sweetness prior to gathering interval or ratio data (Stone & Sidel, 2004).

Interval data involves panellists placing items into groups separated by a constant interval and represent actual quantities, for example:

'How sweet are these cherries?'

0 1 2 3 4 5 6 7 8 9 10 11



Not Sweet **Very Sweet**

Each sample product is placed on the line and an actual numerical quantity is recorded, quite often these scales are a continuous unstructured line with anchor points the ends and possibly a mid-point. Due to the continuous nature of the scale this data is considered parametric and significant differences between products are calculated using analysis of variance (ANOVA). With interval scales zero should not necessarily be considered a true zero. Cherries recorded as 0 on the scale above do not necessarily have no sugar quite the contrary; all cherries have sugar and a relative level of sweetness.

Ratio scales however, always have an absolute zero as panellists are provided with a reference stimulus prior to being asked to assess how many times stronger or weaker a sample is relative to the reference. For example:

'You are first provided with a BING sweet cherry, it has a sweetness score of 10. Now assess the other products assigning them an appropriate number using the scale below.'

0 = no sweetness
5 = half as sweet
10 = sweet
20 = twice as sweet
100 = 10 times sweeter.

Ratio data is preferred by some because it is free from end-of-scale distortions and this type of scale is the most useful in terms of estimating the magnitude of a difference between products. Similar to interval data there is a continuous nature to the scale with no discrete values i.e. the data is parametric, therefore any significant differences between the products can be calculated using ANOVA.

1.7.3. Descriptive Analysis Techniques

All descriptive analysis techniques involve the detection (discrimination) and the description of both qualitative and quantitative sensory aspects of a product by trained panellists, typically 5-100 subjects depending on the objective of the test (Meilgaard *et al.* 2006). These types of test are designed to reflect a total sensory description, taking into account all sensations that are perceived – visual, auditory, olfactory, kinaesthetic, etc – when a sample is being evaluated (Stone & Sidel, 2004). Panellists must also learn to differentiate and rate the quantitative or intensity aspects of a sample and to define to what magnitude each characteristic or qualitative note is present in a particular sample. Quite often two different products can share similarities in their qualitative descriptors, but they then differ markedly in the intensity of each and the result is two different and easily distinguishable sensory profiles.

There are four different components to descriptive analysis (Meilgaard *et al.*,2006):

1. Characteristics: the qualitative aspect
2. Intensity: the quantitative aspect
3. Order of Appearance: the time aspect
4. Overall Impression: the integrated aspect

The qualitative aspect refers to the perceived parameters that define a sample and these parameters are referred to by various terms such as attributes, characteristics, character notes, descriptive terms, descriptors or terminology (Meilgaard *et al.*, 2006). Such qualitative factors provide terms that define the sensory profile of a sample or product. An important issue to consider is that panellists, unless well-trained, quite often have very different ideas or concepts of what they mean by a particular term. The selection of sensory attributes and their corresponding definitions should be referenced to real chemical and physical properties of a product that can be perceived (Civille & Lawless, 1986). Observing and understanding a product's physics or chemistry makes the descriptive data easier to interpret and make key decisions about a product based on this data. Statistical methods such as ANOVA, Friedman or multivariate analysis can be applied to aid selection of the more discriminating terms (Meilgaard *et al.*, 2006).

The quantitative aspect of descriptive analysis illustrates the degree of the presence of each characteristic or attribute used to describe the product/sample. This is achieved by the assignment of some value along a measurement scale. The validity and reliability of intensity measurements and the descriptive terminology are highly dependent upon:

- Selecting an appropriate scaling technique that is broad enough to encompass the full spectrum of parameter intensities and has enough discrete points to identify small differences in intensity between samples
- The thorough training of panellists to reach a consensus in the way they use the scales across all samples over time.
- The use of reference scales for intensity of different properties to ensure consistent use of scales for different intensities of sensory properties across panellists and repeated evaluations

Not only can panels assign attributes (qualitative) to a sample and the intensity (quantitative) of each attribute but they can also detect differences between products in the order in which certain characteristics manifest themselves. The appearance of physical properties is generally predetermined by the way the product is handled for example controlling the manipulation or eating process of a product allows a subject to induce the manifestation of only a limited number of attributes at a time (Civille & Liska, 1975). When the intensity of one or more sensory properties is repeatedly monitored over a designated period of time, this type of technique is referred to as time-intensity analysis (Lee & Pangborn, 1986).

In addition to the panellist's ability to detect and describe qualitative, quantitative and time factors influencing sensory characteristics they are also able to combine these factors in various ways that can give an overall impression of a product. Such assessments could include *total intensity of aroma or flavour*; *balance/blend (amplitude)*; *overall difference.*

Various descriptive analysis methods have been developed over relatively recent years and some are more popular than others. Although some methods are more popular, they are not always considered to be the most appropriate more often than not a sensory analyst must modify or develop an existing method, to adapt it to a specific product or project application. Factors they need to consider when revising

current descriptive analysis methods include selecting a system which will generate the most detailed, accurate and reproducible description of a particular product or the best discrimination between products of a similar group. A very popular method widely used in sensory science across the globe, particularly in the UK and Europe, is that of Quantitative Descriptive Analysis® (Stone & Sidel, 1998); although a new method based on Free-Choice profiling (Williams & Langron, 1997) has been developed called Flash Profiling (Dairou & Sieffermann, 2002) which was designed as a quick substitute for conventional methods where time is limited or as preliminary test prior to the time-consuming conventional method. When using descriptive analysis to assesses a product set of many varieties of sweet cherry the conventional method considered would be QDA® but where time and resource is limited it may be possible to apply the Flash Profile technique.

1.7.4. Quantitative Descriptive Analysis® (QDA)

The QDA® method was originally developed in 1974 (Stone *et al.*, 1997) as sensory experts were becoming dissatisfied with the Flavor Profile® and its related methods, as desired levels of statistical treatment could not be achieved. The QDA® method has a greater dependence on statistical analysis to define suitable terms, procedures and panellists for analysis of a particular product.

A limited number of subjects are selected to form the panel from a broader pool of candidates based on their ability to discriminate and identify differences in sensory properties between samples of a similar product set for which they are to be trained. Training the panel involves providing them with product or ingredient references similar to that observed in other descriptive methods to stimulate the generation of suitable terminology or attributes. A panel leader is required to facilitate this process rather than instruct so as to maintain the panel's independence and not influence the group in any way. This is achieved by using a leader who is non-judgemental, who does not offer opinion (generating bias), who is sensitive and assertive but diplomatic in their approach. They must be an active listener who is able to probe into the meaning of terminology generated without proffering information and can control diverse opinions and personalities to prevent certain panellists dominating and others failing to influence the direction and orientation of any consensus reached. Once agreement has been met amongst panellists on the choice and meaning of terminology, they then use a 15cm (6 inch) line scale that the QDA®

method provides to score the products for each term. The scoring process is then repeated and the data statistically analysed until quantification for each attribute is considered to be consistent; this process can take between 5-120 hours through multiple sessions which is time-consuming and can be very expensive if using a paid external panel.

Once the training described above is completed, the panellists are placed in individual sensory booths (ISO 8589:1988) to reduce any distractions and panellist interaction, and then asked to evaluate products one-by-one, sometimes in multiple sessions depending on the product and the terms being assessed. Panellists are expected not to discuss data, terminology or samples after each assessment session to preserve their independent scoring of the products although they are allowed to speak to the panel leader. The panel leader chooses what information the panellists may be told regarding their performance in relation to the rest of the panel and of any known differences between samples.

The results of the QDA® test are statistically analysed using ANOVA as the scores provided are real values that provide parametric data. The ANOVA provides the basis of identifying assessor effects and product differences and ultimately determines what decisions and outcomes will come from the test. An ANOVA of the data collected between two or more replicate sessions will identify whether each panellist is consistent and repeatable in their scoring and use of the scales (known as intra assessor effect), if not then more training is required. An ANOVA between assessors from one session can determine whether the panellists are using the scales similarly between themselves (known as inter-assessor effect), if not again more training is required. An ANOVA applied to the mean scores of each product will determine whether two or more products differ and on observation of the standard errors (standard deviation) it is possible to determine which products are significantly different or similar to each other. Quite often final reports of a QDA® not only include statistical data to identify subtle or discrete differences but a graphical representation in the form of a spider plot to illustrate the crude differences observed between products.

1.7.5. The Flash Profile

The Flash Profile is a relatively new sensory descriptive method based on a combination of Free Choice Profiling (Williams & Langron, 1984) and comparative

evaluation of a whole product set and it was developed and established by Jean-Marc Sieffermann and his colleagues at the turn of the new millenium (Dairou & Sieffermann, 2002; Delarue & Sieffermann 2004). The basic idea or underlying concept of the Flash Profile is to present the whole product set simultaneously, then each panelist generates their own descriptors corresponding to the major differences they perceive between those products. The panelists then directly rank the products using their chosen descriptors and the procedure is such that assessments run attribute-by-attribute rather than the product-by-product procedure observed in QDA®.

A minimum of 9 panelists are selected based on their previous sensory experience and familiarity with sensory methods but not necessarily with the product itself. This is because the Flash Profile uses Generalized Procrustes Analysis (GPA) to map the products on to a space which is very much dependent on the descriptors generated so the panel must consist of people who understand the panel leader's instructions and are able communicators who can generate discriminating and non-hedonic attributes. Unlike the QDA® method there is no specific product training phase required as the Flash Profile does not rely on consensual descriptors but on each assessors free choice and so the result is that it is less time-consuming and cheaper to run. The Flash Profile was developed to provide quick access to the relative sensory positioning of a set of products without having to train a panel first.

1.7.5.1. Generalised Procrustes Analysis (GPA) Plots

GPA is a projection technique which allows products to be mapped out into shapes within a certain space characterised by multiple variables which in this case are the attributes generated by the panel. Principal component analysis (PCA) is a similar method that could be used to map out each judges response on separate judge spaces but the advantage of the GPA is that all the judges and the variance observed in their variables (attributes) can be placed on one chart, in a consensus space. This is achieved through a symmetrical analysis, which means all individual sets (each judge's data) must use the same number of attributes. This is not the case as different judges generate different numbers of attributes however, this is overcome by generating attributes containing only zeros to each of the sets until they are all equal. The sets are then aligned by rotating and scaling them, which minimises the Procrustes criterion, which measures the difference between the consensus space and

the individual spaces for each judge. When the difference is small enough, the spaces are averaged to produce the consensus space. This now allows the experimenter to extract multiple principal components from the data set by a regular PCA (Gower, 1975; Dijksterhuis, 1997). There are limitations based on loss of variance in this type of projection method but this will be discussed with the data generated in the following experiments.

1.7.6. Consumer Sensory Testing

There are a range of consumer tests available and a range of scales which can be used when undertaking a consumer test, but the most appropriate technique, like most sensory tests, is determined by the type of product being assessed and the objective of the assessment. The objective of this study is not just to determine consumer preference and acceptability but to determine what key factors drive it. To understand this, some descriptive analysis of cherries is required combined with preference and acceptability data and this can be achieved using preference mapping.

There is a debate in the consumer behaviour literature on the use of internal and external preference analysis as to which is more appropriate. Internal preference analysis gives precedence to consumer preferences and uses perceptual information as a complementary source of information whereas external analysis gives priority to perceptual information by building a product map based on attribute ratings and only fits consumer preferences at a later stage. The choice of which is more appropriate can be made by considering the end user (Van Kleef *et al.*, 2006). For marketing purposes it would be better to look at the underlying dimensions of the resulting product maps, believed to describe consumer choice criteria. Interpretation of preference maps for the purpose of this project is to provide insight into the key drivers of consumer preference for the development of effective marketing strategies for the commercial sponsor. This can be achieved by exploring and understanding the variance in consumers' preference scores in order to differentiate segments of consumers with homogenous preferences. In internal preference mapping, more variation in preference is accounted for, whereas external preference analysis is restricted to a small number of consumers that can be significantly fitted to a perceptual space (Greenhoff & MacFie. 1994). However more attribute information is accounted for in the external product map, and understanding consumer product perception is also important, but for the purpose of this project the variance in preference is of greater significance to the commercial sponsor. The Flash Profile will

provide this perceptual product space, albeit of an experienced external sensory panel rather than consumers and the two do not necessarily share the same thought processes in analysis and perception.

The minimum number of consumers needed to obtain viable consumer data will be at least 100 as defined by Hough *et al.* (2006)

1.7.6.1. Internal Preference Mapping

The basis of internal preference mapping is that there is a shared space of preferential perception of a set of foods, beverages or in this case raw cherries that are perceived by each of the consumers. However what drives the liking of individuals may vary according to the sensory properties they like or do not like. Some could be driven by colour, a common perception is that darker cherries are sweeter (Kappel *et al.*, 1996) others could be driven by juiciness. Regarding deterministic preference mapping, it is also assumed that individuals focus on a single or highly correlated group of sensory attributes and could rate the liking of products according to how much or how little of those attributes are present. Following a consumer liking test where-by assessors perform a rank-rating exercise (by ranking preference first before rating samples using the LAM scale) to indicate liking/disliking of the products within the set, a principal component analysis (PCA) can be applied to the data to map out which products were perceived to be similar in terms of preference. The PCA creates a bi-plot polarising and drawing together products and assessors who display similar preferences within the product set, the data from the flash profile and any analytical data can be added in to this bi-plot as supplementary data. The addition of the supplementary data can be used to describe what may be driving their direction of liking in the individual consumers and what perceptions of the products may be linked to this liking. The PCA plot often highlights clusters of consumers whose perception of liking/disliking may be similar and these clusters can be statistically calculated using various methods of cluster analysis.

One such method termed agglomerative hierarchical clustering uses an algorithm which first considers each respondent as a separate cluster. The first stage of any cluster analysis is to define an index of similarity or dissimilarity then the clustering algorithm will segment the respondents/consumers in to clusters. The number of clusters and their membership will be a key factor in understanding the behaviour of the consumer (sample) population and the drivers of preference and

acceptability behind clusters with relatively high membership will be of prime significance to the commercial sponsor of this project. (Dijksterhuis, 1997)

1.8. Hypotheses

a) The Flash Profile is a viable method which can provide a comprehensive sensory profile suitable for descriptive analysis.

b) The interpretation of Flash Profile data combined with the interpretation of an extended internal preference map can be used to expose the key drivers behind consumer preference and acceptability of sweet cherries.

2. Southern Hemisphere Season – Flash Profile Method development

The aim of this southern hemisphere season was to optimise the methods applied to the sensory analysis experiments being undertaken in the northern hemisphere season. Two sensory analysis experiments were undertaken using the Flash Profile technique (Dairou & Sieffermann, 2002).

2.1. Flash Profile Using 8 samples of sweet cherry

The Flash Profile is a relatively new technique and so publications of previous studies were limited but, of those publications, the number of samples assessed by judges varied from as high as 14 to as low as 5 (Dairou & Sieffermann, 2002; Delarue & Sieffermann 2003; Rason et al., 2006). The products assessed in these studies included sausages, dairy products and jams, all of which were processed in some form or another, unlike sweet cherries which were natural. These processed products are likely to have a certain level of homogenous character as the processes in making them are often controlled by quality controls and assessments (QC & QA), however sweet cherries have a more heterogeneous character due to their natural variation. As in most descriptive sensory experiments, judge repeatability is an important factor in validating the results and this natural variation in the product may distort judge repeatability. The judges may be consistent in their assessment of the various characteristics of the products but the products themselves may vary and this could prove to be difficult when statistically validating repeatability. Therefore the number of cherry samples and the size of the samples assessed needed to be considered carefully so as not to overwhelm the judges and produce highly inconsistent meaningless data. The first experiment undertaken involved 12 samples of cherry and this proved to be the case (data not shown) and so, the first experiment reported, involved only 8 cherry samples. In both experiments, 4 whole cherries were presented in an individual sample to account for the natural variation and the assessors were to evaluate all four cherries before outlining their response.

Panel recruitment size was another issue that needed to be considered as the previous studies (cited above) used panel sizes from 6 to 10 judges who all had previous experience with other sensory panels but not necessarily with the product being assessed. The advantage of this was that they had a relatively good descriptive

ability and were able to follow instructions laid out by panel leaders from other sensory analyses. So, with this in mind, 9 judges who were familiar to sensory panels but not panels involving cherries were selected, all from the Department of Food Sciences at the University of Nottingham.

2.1.1. Methods

2.1.1.1. Selection of the sweet cherry samples

8 samples of cherry were imported to the U.K. by Norton Folgate Ltd. and sent to the University of Nottingham's School of Biosciences, Sutton Bonington. All the samples originated from Chile with the exception of one 'early' sample sourced from Argentina. The samples were selected to reflect the time/age of cherries post harvest normally retailed by the producers to the consumers.

2.1.1.2. Sensory Panel

A panel of 9 judges, 5 men and 4 women, aged from 19 to 60 years were recruited for their experience in sensory analysis methodology, through participating in other sensory tests prior to this one. Previous sensory testing experience was required to generate original attributes for the description and discrimination of the products. Ethical approval from the University of Nottingham ethics committee for the use of human subjects in these experiments was not pursued as it was deemed unnecessary as the products had not undergone any preparation or manipulation and they were 100% natural and formed part of normal human diet.

2.1.1.3. Sensory Evaluation

The Flash Profile was performed using the procedure defined by Dairou & Sieffermann (2002). However in this test, assessments of each characteristic (attribute) chosen by each judge were performed in duplicate (Rason et al., 2006) whereas the original (Dairou & Sieffermann, 2002) involved three replications. The first session involved each judge individually generating their own list of descriptive terms. All 8 samples of sweet cherry were presented simultaneously and the terms were generated, then categorised as appearance, texture, aroma or flavour. The judges were asked to list the sensory attributes which were ideal for describing the

differences they perceived between the sweet cherry samples and they were instructed to avoid hedonic terms. The length of this session averaged at approximately 30 min. and ranged from 20-35 min. Between the first and the second session the all attributes generated by the panel were compiled in a list. At the beginning of the second session, judges were asked to read the panel's list and to update their own list if desired. The judges individually proceeded to the evaluation itself on a ranking mode where ties are allowed, using their own definitive list of terms. Eight samples of sweet cherries were presented simultaneously, balanced in a randomised order for the judges to taste. Following first tastes of each sample, judges were able to re-taste the sweet cherries as much as they desired. Pauses were allowed during the evaluation to avoid reduced sensitivity on the palate. The third session was a replicate of the second session. The two evaluation sessions (sessions 2 & 3) lasted approximately 60-70 minutes each and all sessions were conducted in standardised booths (ISO 8589:1988).

Data was collected manually with judges recording their responses to the first session in writing and the two subsequent sessions by ranking products on the blank scales provided. In order to uncover the true meaning of each description judges could use their own anchors for these scales if desired. An example of this was the attribute 'Red' where the judge responded with light and dark as anchors for the scale before ranking the products for this attribute (see appendix for manual response forms).

2.1.1.4. Protocol for Sample Presentation

Cherry samples (4 whole cherries) were presented in identical white polystyrene pots, each labelled with a randomly generated 3 digit code, in a randomised, balanced order across the panellists. All 8 samples were presented simultaneously in each individual session in the booths and only 2-3 attributes were assessed in a single session in the booth then a 10 minute break was given. Samples were removed from refrigeration (4-6°C) no less than 2 hours before presentation for assessment so that the samples could reach room temperature.

2.1.1.5. Statistical processing of Flash Profile data

The repeatability of each judge for each sensory attribute between the two evaluation sessions was analysed using the test defining the Spearmann Correlation Co-efficient. The discriminant ability of each attribute per judge was tested using a

one way analysis of variance (ANOVA) on the rank data. Rank data is non-parametric and should be analysed using a Friedman's test, but this test cannot handle replications, so ANOVA was performed. A limitation of applying ANOVA instead of Friedman's to rank data is that the distance on a scale between rank positions 2 & 3 could be much bigger than 3 & 4 yet ANOVA will assume there is a uniform level of difference between each ranking. This will be discussed with the other statistical limitations of the method in the project review chapter (Chapter 4.1.1). Generalised Procrustes Analysis (GPA) was applied to the data from the Flash Profile to assess the consensus between judges' sensory map. The GPA calculates a consensus from data matrices of a sensory profiling experiment. In this experiment a data matrix corresponds to each judge. This consensus should reflect the true underlying data structure and indicate which products are similar and which ones differ strongly from each other on the GPA plot. The Spearmann Correlation Co-efficient (SCC) test, ANOVA and GPA were performed using the XLSTAT add-in for Microsoft Excel.

2.1.2. Results

2.1.2.1. Validation of the assessment of each judge: repeatability and discrimination ability

The repeatability of the judges between the two evaluation sessions was tested by the Spearmann correlation test (data not shown). An attribute is considered as repeatable if the evaluated attribute from both the first and second evaluation session are significantly correlated, at a significance level of $p<0.05$.

Table 2.1: F-value from ANOVA on sensory attributes of each judge of Flash Profile
*p<0.1, **p<0.05, ***p<0.01 and ****p<0.001

Judge 1	F-value	Judge 2	F-value	Judge 3	F-value
Size	11.94****	Red	12.11****	Sweet	3.19*
Red skin	16.1****	Size	7.15***	Soft (TF)	2.29
Red flesh	9.76**	Smooth	3.09*	Shade	2.73
Firm (TM)	2.17	Firm (TM)	0.92	Juicy	2.17
Juicy	3.57*	Juicy	0.57	Size	10.86***
Sweet	6.86**	Sweet	0.45		
Bitter	3.66*	Acidic	1.99		
Astringent	1.77	Cherry	0.86		

Judge 4	F-value	Judge 5	F-value	Judge 6	F-value
Red	12.57****	Strength (F)	8.17***	Shade	5.98**
Firm flesh	0.52	Size	8.78***	Fruity	2.41
Juicy	1.43	Consistent Colour	6.45***	Juicy	7.52***
Sweet	13.28****	Juicy	4.71**	Sweet	2.92*
Bitter	1.26	Firm (TF)	0.94	Dry	1.76
Acidic	3.374*				

Judge 7	F-value	Judge 8	F-value	Judge 9	F-value
Flesh colour	2.86*	Shade	3.94**	Colour	0.60
Red Skin	2.86*	Firm (TM)	1.54	Soft (TF)	1.04
Hard (TF)	1.45	Juicy	2.86*	Soft (TM)	0.86
Soft (TM)	0.815	Sour	3.51**	Cherry (A)	1.60
Sweet	3.91**	Sweet	6.69***	Sweet	0.46
Sour	2.73*	Strength (F)	4.21**	Sour	0.86
Juicy	2.62*				

Table 2.2: List of attributes generated and used by the panel for the Flash Profile

Modality/attribute	Number of judges using the same attribute
Appearance	
Red	2
Flesh Colour	1
Consistent colour	1
Red skin	2
Red flesh	1
Size	4
Smoothness	1
Shade	3
Colour	1
Texture by fingers (TF)	
Hard	1
Firm	1
Soft	2
Texture by mouth (TM)	
Soft	1
Juicy	8
Astringent	1
Firm	3
Firm flesh	1
Dry	1
Aroma	
Cherry	2
Flavour	
Sour	3
Sweet	8
Strength	2
Bitter	2
Acidic	2
Fruity	1

Judge 1 was the most reproducible with 4 attributes out of the 8 generated and Judge 5 was reproducible for 2 attributes out of 5 generated. The least reproducible judges were Judge 7 and 9 with 0 attributes each out of 7 and 6 generated respectively. Most judges were repeatable for appearance (some colour, some size, some both). Only the reproducible attributes should be kept for the next analysis, but due to the natural variation of the fruit within an individual sample this made it extremely difficult to account for the repeatability of judges. On observation and consumption of a few fruits it was clear to see that the fruit did have a high level of natural variation. As mentioned earlier at the beginning of chapter 2.1 processed products often have QA & QC during production generating a relatively uniform homogenous product but with fruit being natural it has a heterogeneous character. Thus the source of this lack of repeatability was questionable could it be due to inconsistent judging or inconsistent products? So the two evaluation sessions were treated separately and separate GPA plots were generated and comparisons could be made between the two plots. The discriminant ability of the judges for each attribute was analysed using a one way ANOVA (Table 2.1), only the attributes considered significant were used to generate the GPA plots.

2.1.2.2. Diversity of the attributes generated and used by the panel

Each of the nine judges generated 5-8 attributes for a total of 55 attributes. The list of the attributes generated and used by the panel is summarised in Table 2.2. Sweet (flavour) and juicy (texture in mouth) were popular attributes with 8 out of 9 judges selecting these attributes. Generally the attributes used by the panel described appearance, particularly colour, texture and flavour.

From the GPA performed on the data from the first evaluation session, it appears that there are 3 factors accounting for 91% of the total variation between the products from the whole set of samples. Factors 1, 2 and 3 acounted for 52%, 28% and 11% respectively of the total variation within the product set. The GPA plot of F1 vs F2 displayed 79% of the total variation and showed that some identical attributes have a similar meaning for the different judges. On inspection of the GPA plot F1 vs. F2 from the first evaluation session (Fig. 2.1A), axis 1 appears to define colour and all the judges assessing colour appear to have a similar perception of the attribute with the exception of judge 7 who on inspection of the raw data used the scale of colour opposite to the others. This can be seen on the plot with all the attributes associated with colour lying in the positive part of axis 1 with judge 7 as the exception. It appears that those lying in the positive part of axis 1 are darker cherries and those in the negative part are a relatively lighter shade of red.

Most of the sweet attributes are close to the bottom of axis 2 and lie in the positive region of axis 1 (i.e. located in the bottom right quadrant). In addition to this, sour which could be considered an opposite to sweet is located in the top left quadrant closer to axis 2 than axis 1. This suggests that axis 2 roughly corresponds to a sweet/sour axis but with a slight anti-clockwise skew, with negative values implying the cherries are sweet in relation to the whole product set and positive values implying cherries are sour. The 'Size' attribute appears to be correlated with sweetness as they lie relatively close on the GPA plot (2.1A) and this is common knowledge to those in the industry that the two are linked, as 25% of the final fruit weight is added in the last week prior to harvesting as sugar is accumulated (Looney *et al.* 1996)

Variation in F3 accounted for 11% of the total variation (data not shown) but this factor was difficult to characterise as there were significant correlations associated with attributes from three categories, texture, appearance and flavour.

2.1A

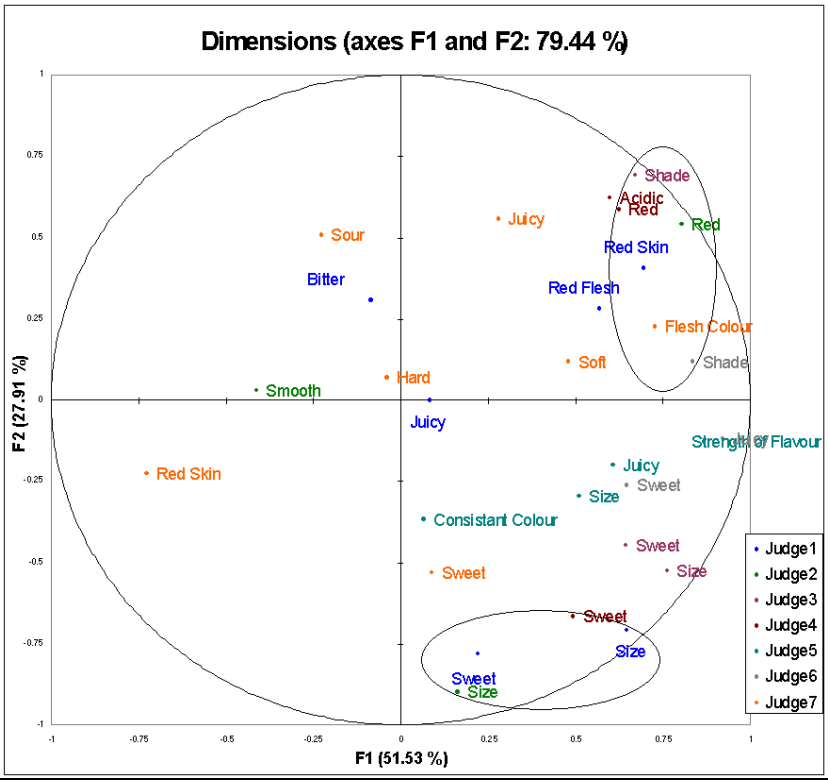
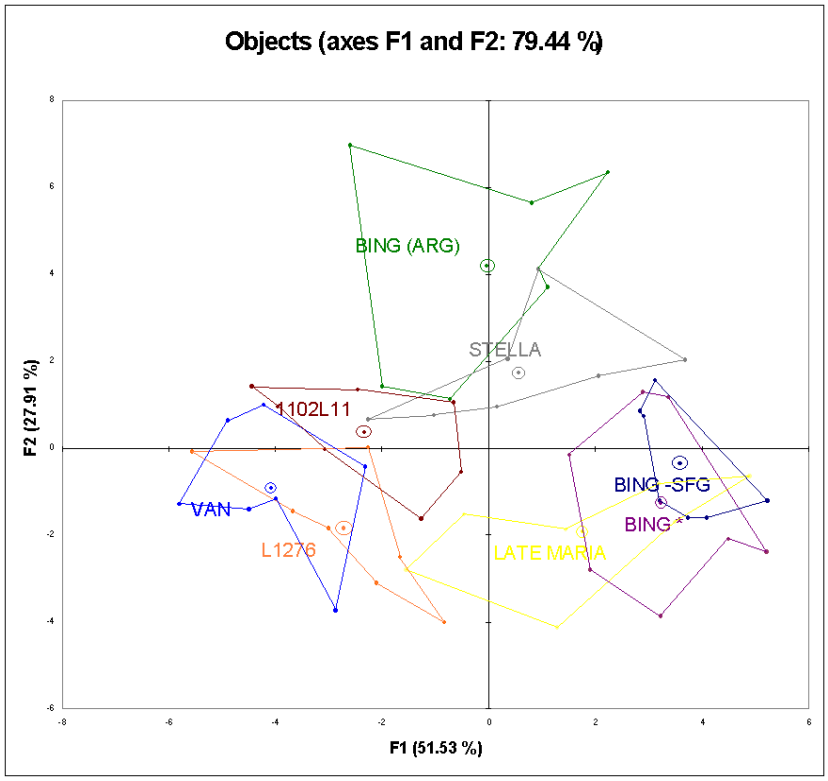


Figure 2.1: Plots of the GPA performed on the sensory data from the first evaluation session. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).

2.1B



From the GPA performed on the data from the second evaluation session, it appears that there are again 3 factors accounting for the majority (94%) of the variation. Factors 1, 2 and 3 accounted for 56%, 29% and 9%. The GPA plot of F1 vs. F2 accounted for 82% of the total variation compared to 79% observed in the first evaluation session. The plot of F1 vs. F2 showed that some of the appearance/colour attributes have a similar meaning for the different judges. On inspection of the GPA plot F1 vs. F2 from the second evaluation session (Fig. 2.2A), axis 1 again appears to define colour and all the judges assessing colour appear to have a similar meaning with the exception of the same judge (7), who on inspection of the raw data continued to use the scale of colour opposite to the others. There is a clear similarity in the axis of factor 1 between the first and second evaluation with the darker cherries displaying positive values in both sessions. It can be concluded that those lying in the positive part of axis 1 are the darker cherries and those in the negative part are a lighter shade of red. In the second evaluation session, size appears to have more influence on F1 than F2 as seen in the first session as it displays a much stronger correlation with F1 in this session.

Similarly to the first evaluation session most of the sweet attributes are close to the bottom of axis 2 and lie in the positive region of axis 1 (i.e. located in the bottom right quadrant). In addition to this, sour which could be considered opposite to sweet, is located in the top left quadrant closer to axis 2 than axis 1. This suggests that again axis 2 roughly corresponds to a sweet/sour axis but with a slight anti-clockwise skew, with negative values implying the cherries are sweet in relation to the whole product set and positive values implying cherries are sour.

Unlike the first evaluation session variation in factor 3 of the second evaluation session can be loosely linked to texture although there is no significant evidence to conclude this (data not shown). On observation of the correlations between dimensions and factors for each judge, attributes such as hard, soft and smooth appear to be significant to some judges but not to others. This suggests that factor 3 could roughly correspond to a texture axis of hard/soft but the evidence is inconclusive as the numbers of judges who display significant correlations make up a minority of the panel.

2.2 A

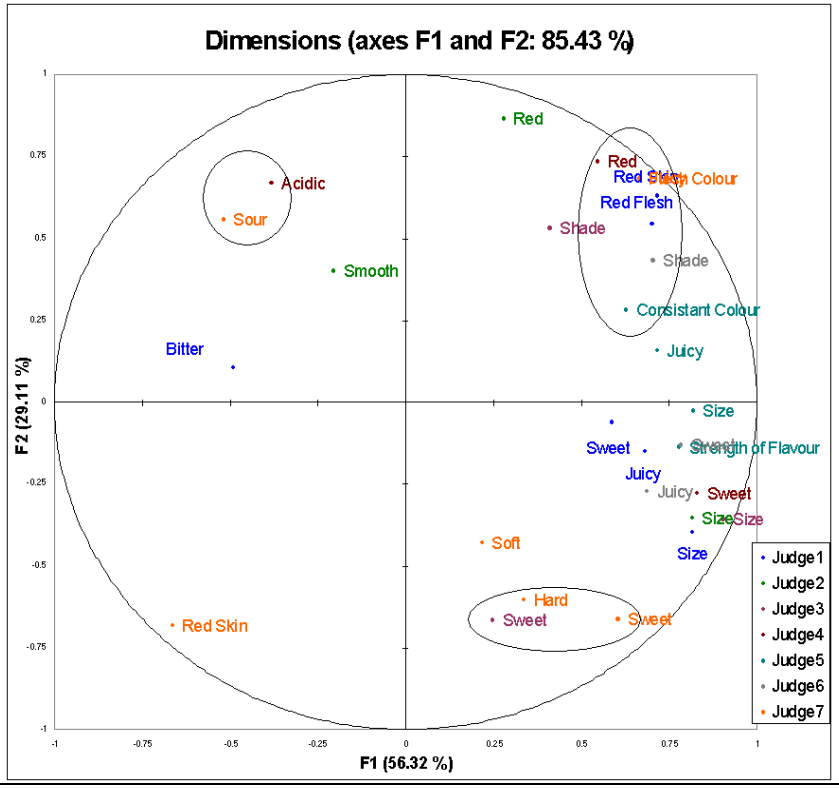
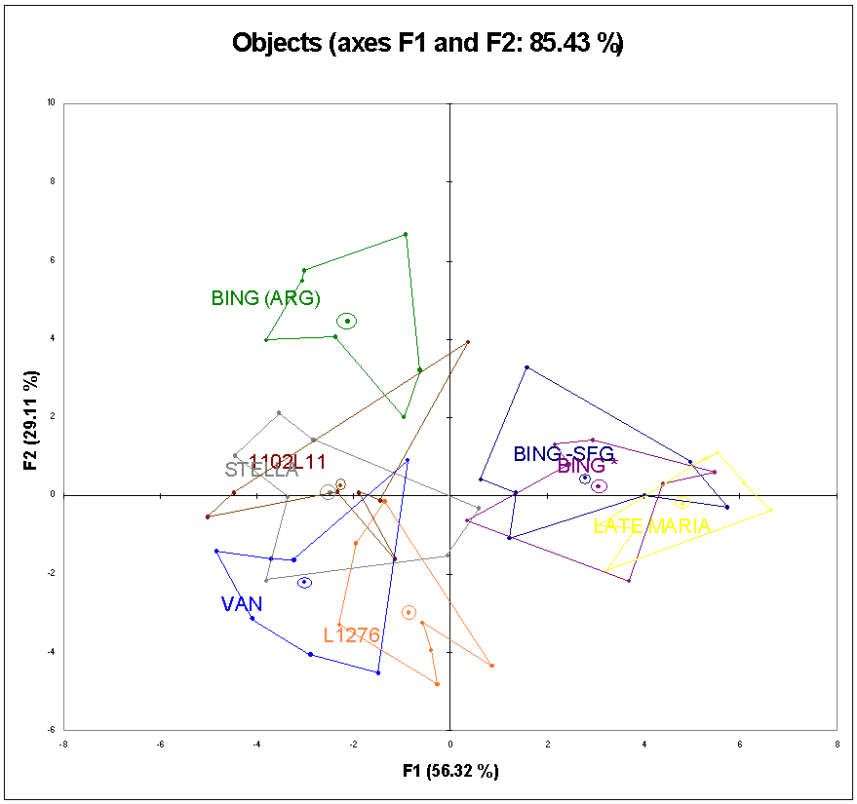


Figure 2.2: Plots of the GPA performed on the sensory data from the second evaluation session. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).

2.2 B



2.1.2.3. The relative sensory positioning of fresh sweet cherries

The plots of F1 vs. F2 from both evaluation sessions discriminate VAN, L1276 and 1102L11 from BING-SFG, BING* and LATE MARIA (Figs. 2.1A and 2.2A). This first axis was characterised by colour of appearance with the first three mentioned above being a significantly lighter shade of red and the latter much darker than the average of the whole product set. BING (ARG) and STELLA lay between the two groups in the first evaluation and could not be discriminated from the other products solely by colour of appearance (axis 1). However in the second evaluation session both BING (ARG) and STELLA were scored as a brighter or lighter shade of cherry matching the group of VAN, L1276 and 1102L11. BING (ARG) was discriminated from all the other products in the set on axis 2 in both evaluation sessions. It displays a characteristic of sourness or a lot less sweetness compared to the rest. This was probably due to these cherries being one of the first harvests of the Argentinean season and so the fruits had not matured on the tree prior to harvest to grow and develop the sweetness or size that the other products had. All the other products displayed a sweeter characteristic than the Argentinean Bing as they were from Chile where it was mid-season and so the cherries would have had ample time to mature on the tree and accumulate sugar to the desired levels.

2.1.3. Discussion

The results were encouraging in that Flash Profiling is a technique which has a lot of potential in descriptive sensory analysis. The GPA plots were able to sufficiently group cherry samples which were similar, yet differentiate between groups displaying different characteristics based on colour, sweetness and size. It was also able to illustrate attributes which are known to be highly correlated such as sweetness and size (Looney et al, 1996) as these attributes were clustered (visually rather than statistically) on the attribute plots.

The statistical level of significance of an ANOVA is usually set at 95% (Dairou & Sieffermann, 2002; Delarue & Sieffermann, 2003; Rason et al., 2006) but this generated only 20 attributes displaying a significant difference from 7 of the 9

judges on the panel. The plots generated were considered to be 'thin' as only a limited number of attributes were displayed on the plots and these attributes were located in and around the central areas. The lack of correlations between the attributes and the two prime factors of variation made it very difficult to characterise what the plots were illustrating and thus even more difficult to characterise the products. As the objective of this experiment was to develop the method for both practicalities and statistical analysis the level of significance was altered to 90% whereby 30 attributes displayed a significant difference between the cherry samples from 7 of the 9 judges on the panel. It also displayed attributes which were correlated much closer to the two main factors of variation and this allowed comparisons and contrasts to be drawn between the cherry samples. The justification of tolerating a lower level of significance was due to the heterogeneous character brought about by the natural variation in the product.

It was also noted that the cherry samples in both sessions were characterised by the same attributes located in very similar positions on each of the two plots. The products too showed this similarity in their positioning with the exception of Stella and Bing (ARG). This suggested that the judges showed some level of consistency between the two sessions even though the SCC suggested this was not the case.

2.2. Flash Profile Using 6 samples of sweet cherry

The previous Flash Profile undertaken used (Chapter 2.1) 8 samples of cherry, some of which proved to be very similar and others very different in the characteristics they displayed. In order to test the discriminating ability of the Flash Profile technique, a request was put to Norton Folgate Ltd. (the cherry supplier and commercial sponsor of the project) to select and send what they considered to be varieties of cherry with much more distinct differences than the samples used in the previous Flash Profile. Only 6 samples were chosen for this experiment to see if the sample size would affect the judge's ability to discriminate; as they had fewer samples to assess it was believed they would have more time to focus on and assess the differences resulting hopefully in better discrimination of the samples within the set.

Panel recruitment size remained at 9 judges even though 1 judge in the previous experiment was unable to perceive any significant differences and a second judge was removed as only a very small proportion of the variance perceived by this judge could be explained by the factors displayed in the plots (F1 and F2). So the GPA plots were formed based on observations from only 7 of the 9 judges involved in the sensory analysis. A completely new panel was selected from that used in the previous Flash Profile but again they were sourced from the Department of Food Sciences at the University of Nottingham because they had previous experience with sensory panels which was one of the requirements of the Flash Profile protocol (Dairou & Siefferemann, 2002).

2.2.1. Methods

2.2.1.1. Selection of the sweet cherry samples

6 samples of cherry were imported to the U.K. by Norton Folgate Ltd. and sent to the University of Nottingham's School of Biosciences, Sutton Bonington. All the samples originated from Chile with the exception of one 'early' sample sourced from Argentina. The samples were selected to reflect the time/age of cherries since harvest normally retailed by the producers to the consumers.

2.2.1.2. Sensory Panel

A panel of 9 judges, 4 men and 5 women, aged from 19 to 26 years were recruited for their experience in sensory analysis methodology, through participating in other sensory tests prior to this one. Previous sensory testing experience was required to generate original attributes for the description and discrimination of the products. Ethical approval from the University of Nottingham ethics committee for the use of human subjects in these experiments was not pursued as it was deemed unnecessary as the products had not undergone any preparation or manipulation and they were 100% natural and formed part of normal human diet.

2.2.1.3. Sensory Evaluation

Refer to Chapter 2.1.1.3 – but note where 8 samples are stated only 6 were used in this experiment.

2.2.1.4. Protocol for Sample Presentation

Refer to Chapter 2.1.1.4 – but note where 8 samples are stated only 6 were used in this experiment.

2.2.1.5. Statistical processing of Flash Profile data

Refer to Chapter 2.1.1.5

2.2.2. Results

2.2.2.1. Validation of the assessment of each judge: repeatability and discrimination ability

The repeatability of the judges between the two evaluation sessions was tested by the Spearmann correlation test (data not shown). An attribute is considered as repeatable if the evaluated attribute from both the first and second evaluation session are significantly correlated, at a significance level of $p<0.05$. 'Judge 4' was the most reproducible with 3 attributes out of the 4 generated and 'Judge 8' was reproducible for 4 attributes out of 7 generated. The least reproducible judge was 'Judge 5' with 1 attribute out of 13 generated. Most judges were repeatable for appearance (some colour, some size, some both). Only the reproducible attributes should be kept for the next analysis, but due to the inconsistency of the fruit within a sample this made it extremely difficult to account for the repeatability of judges. On observation and consumption of a few fruits it was clear to see that the fruit had a high level of variation. Processed products often have quality controls during production which generate a uniform product but with fruit being natural this is not the case. Was the lack of repeatability due to inconsistent judging or inconsistent products? The result was that the two evaluation sessions were treated separately and separate GPA plots were generated and comparisons could be made between the two plots. The

Modality/attribute	Number of judges using the same attribute
Appearance	
Dark Skin	5
Red	4
Glossy	3
Dark	2
Shiny	1
Spotty	3
Dark Flesh	3
Dark Juice	1
Size	1
Texture by fingers (TF)	
Smooth	2
Ripe	1
Hard (TF)	3
Firm (TF)	5
Soft (TF)	1
Spongy (TF)	1
Bumpy (TF)	1
Texture by mouth (TM)	
Juicy	7
Hard	1
Chewy	3
Pulpy	1
Crisp	3
Soft (TM)	1
Crunchy	1
Firm (TM)	4
Skin Thickness	1
Puncture Easy	1
Aroma	
Apple (A)	1
Sweet (A)	1
Green (A)	1
Cherry (A)	1
Fruity (A)	1
Flavour	
Deep	1
Flat	1
Zingy	1
Fruity (F)	2
Cherry	2
Sweet	6
Back of Throat Sweetness	1
Sour	3
Acidic	3
Tangy	2
Bitter	2
Strength (F)	2

Table 2.3: List of attributes generated and used by the panel for the Flash Profile

discriminant ability of the judges for each attribute was analysed using a one way ANOVA (Table 2.4), only the attributes considered significant were used to generate the GPA plots.

2.2.2.2. Diversity of the attributes generated and used by the panel

Each of the nine judges generated 6-14 attributes for a total of 91 attributes. The list of the attributes generated and used by the panel is summarised in Table 2.3. Sweet (flavour) and juicy (texture in mouth) were popular attributes with 6 and 7 out of 9 judges selecting these attributes. Generally the attributes used by the panel described appearance particularly colour, texture and flavour.

From the GPA performed on the data from the first evaluation session, it appears that there are 3 factors accounting for 84% of the total variation between the products from the whole set of samples; with factors 1, 2 and 3 accounting for 39%, 27% and 18% respectively. GPA plots can only project two factors simultaneously in a 2 dimensional format so a plot of F1 vs. F2 displaying 66% of the total variation was created and one that illustrates F1 vs. F3 displaying 57% of the total variation. The plots show that some identical attributes have a similar meaning for

Table 2.4: F-value from ANOVA on sensory attributes of each judge of Flash Profile
*p<0.1, **p<0.05, ***p<0.01 and ****p<0.001

Judge 1	F-value	Judge 2	F-value	Judge 3	F-value
Hard (TF)	0.71	Red	9.84***	Red	2.08
Zingy	2.84	Glossy	4.05*	Shiny	1.35
Flat	3.28*	Ripe	0.25	Firm (TF)	4.05*
Deep	3.90*	Firm (TF)	4.05*	Soft (TF)	4.05*
Fruity (F)	6.00**	Smooth	2.03	Spongy (TF)	1.60
Dark skin	3.00	Juicy	40.80****	Juicy	12.80***
Red	7.20**	Chewy	0.71	Soft (TM)	3.47*
Crisp	2.65	Hard (TM)	3.47*	Firm (TM)	3.47*
Pulpy	11.54***	Cherry (A)	0.42	Crunchy	2.62
		Sweet	3.47*	Fruity (A)	0.51
		Back of throat sweetness	1.13	Sweet	1.35
		Fruity (F)	19.80****	Sour	1.13
				Acidic	7.20**
				Tangy	11.54***

Judge 4	F-value	Judge 5	F-value	Judge 6	F-value
Hard (TF)	1.31	Dark skin	6.69**	Dark skin	39.60****
Dark	40.80****	Dark flesh	7.20**	Acidic	1.80
Juicy	16.93***	Spotty	5.23**	Firm (TM)	1.77
Skin thickness	1.43	Firm (TF)	3.75*	Chewy	0.07
Spotty	2.37	Smooth (TF)	4.51**	Bitter	5.80**
Sweet (F)	11.54***	Juicy	7.39**	Puncture easy	3.10
Acidic	2.60	Crisp	6.69**		
Sweet (A)	8.40**	Chewy	12.00***		
		Green (A)	1.60		
		Cherry (A)	0.10		
		Sweet (F)	3.90*		
		Sour (F)	0.62		
		Cherry (F)	4.51**		

Judge 7	F-value	Judge 8	F-value	Judge 9	F-value
Dark skin	19.80****	Dark skin	48.00***	Red	7.20**
Firm (TF)	2.51	Glossy	5.33**	Dark	19.80****
Size	8.54**	Firm (TF)	6.23**	Firm (TM)	2.30
Strength	2.51	Crisp	37.20****	Sweet	3.00
Dark flesh	7.87**	Firm (TM)	3.67*	Bitter	5.88**
Hard (TF)	6.00**	Juicy	8.26**	Juicy	3.47*
Glossy	2.65	Apple (A)	1.58	Strength (F)	40.80****
Bumpy (TF)	0.22	Sweet (F)	0.71		
Dark Juice	2.65	Sour	3.53*		
Juicy	5.42**	Tangy	1.03		
		Spotty	53.2****		
		Dark flesh	53.2****		

the different judges. On inspection of the GPA plot F1 vs. F2 from the first evaluation session (Fig. 2.3A), axis 1 appears to define colour and all the judges assessing colour

appear to have a similar meaning with the exception of two judges (1 & 2) who on inspection of the raw data assessed colour of red by brightness rather than darkness. This can be seen on the plot with all the attributes associated with colour/darkness lying in the positive part of axis 1 with the two judges as exceptions. It appears that those lying in the positive part of axis 1 are darker cherries and those in the negative part are a relatively lighter shade of red. The evidence suggests that the main factor of variation that all the judges can account for in the product set is appearance/colour.

The second factor is not as 'clear cut' to define, for some judges it is attributes associated with flavour, for others it is texture. Axis 2 is predominated with flavour attributes as there are more correlations to axis 2 than the texture attributes. It appears that there is a good correlation between texture in mouth and flavour with judge's perceptions seemingly being that soft juicy cherries in the mouth yield more flavour and the hard cherries in mouth lack flavour. This can be seen on the plot because soft/juicy attributes and those associated with flavour lie in close proximity of each other (top Fig. 2.3A). Most of the flavour attributes are close to the top of axis 2 and lie in the positive region of axis 1 (i.e. located in the top right quadrant). This suggests that axis 2 roughly corresponds to a Flavoursome/Bland axis but with a slight clockwise skew; with positive values implying the cherries are soft and have ample flavour in relation to the whole product set and negative values implying cherries are hard and lack flavour. There is also a soft/hard (in mouth) axis closely linked to F2 but with a slight anti-clockwise skew.

Figure 2.3C from the first evaluation session; shows that F3 has a close association with texture (or more specifically texture in the fingers) for the judges whose texture attributes were not accounted for in F2. Judge 4 appears to have a high correlation with F3 for texture attributes associated with holding the cherries in the fingers, where those in the mouth were highly correlated to F2 instead. This also appears to be the case with Judge 7 whose attribute for 'hard' was highly correlated to F3 and was also measured by the fingers whereas their 'juicy' was measured in the mouth and was highly correlated to F2. There are a couple of correlations between in mouth texture attributes and F3 but it is dominated by textural attributes measured by holding cherries in the fingers rather than assessment in mouth. F3 or axis 3 roughly corresponds to texture in the fingers with the hard/firm cherries lying in the negative part of the axis and the soft cherries lying in the positive part. From the GPA performed on the data from the second evaluation session (Fig 2.4), it appears there

are 3 factors accounting for 85% of the total variation between the products from the whole set of samples; with factors 1, 2 and 3 accounting for 36%, 27% and 18% respectively. GPA plots can only project two factors simultaneously in a 2 dimensional format so two plots were created, a plot of F1 vs. F2 (Fig 2.4A) displaying 66% of the total variation and one that illustrates F1 vs. F3 (Fig 2.4C) displaying 58% of the total variation. The plots show that some identical attributes have a similar meaning for the different judges. On inspection of the GPA plot F1 vs. F2 from the second evaluation session (Fig. 2.4A), axis 1 appears to define colour of appearance and all the judges assessing colour appear to have a similar meaning with the exception of the same two judges (1 & 2) from the first evaluation who on inspection of the raw data continued to assess colour of red by brightness rather than darkness. This can be seen on the plot with all the attributes associated with colour/darkness lying in the positive part of axis 1 with the two judges as exceptions. It appears that those lying in the positive part of axis 1 are darker cherries and those in the negative part are a relatively lighter shade of red. The evidence from both evaluations suggests that the main factor of variation that all the judges can account for in the product set is appearance/colour.

F2's axis from the second evaluation has a very similar character to that seen in the first. The axis is predominated by flavour attributes, but again these flavour attributes are highly correlated with being juicy. It suggests that the flavoursome cherries are juicy or that juicy cherries may enhance the flavour. Axis 2 displays a flavoursome/bland axis with positive values implying strong flavour and negative values bland or tasteless. F3 is characterised by texture with attributes such as firm, hard, juicy and soft highly correlated to this axis. The cherries with negative values appear to be hard and firm and those with positive values are soft and juicy.

Both evaluation sessions display similar characteristics when projected on GPA plots; Factors 1, 2 and 3 are highly correlated to colour of appearance, flavour intensity and texture respectively. There are also similarities in the sensory positioning of the products between the two evaluation sessions.

2.3 A

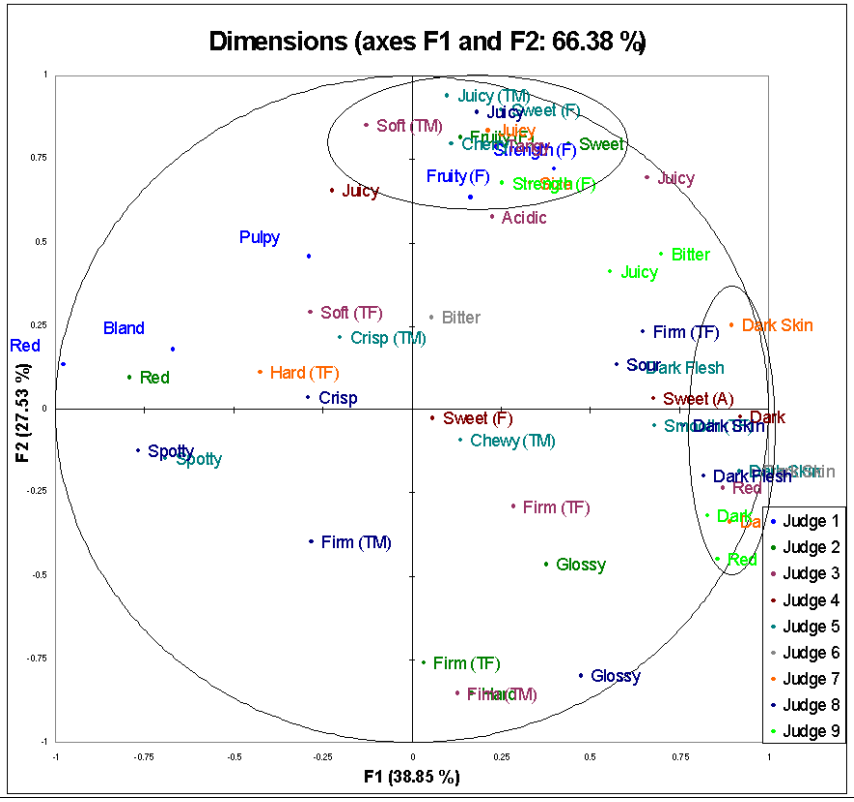
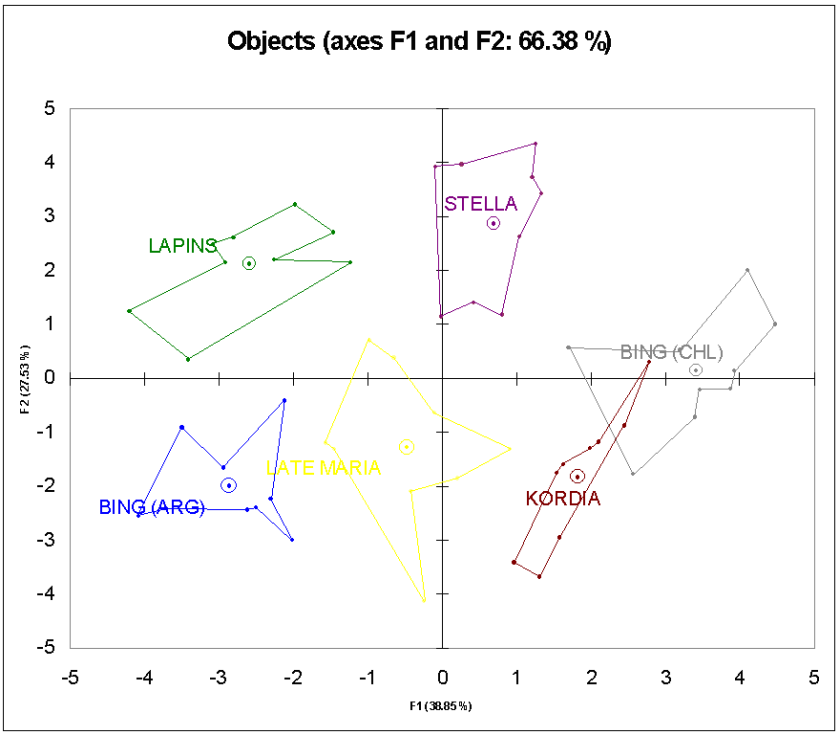


Figure 2.3: Plots of the GPA performed on the sensory data from the first evaluation session. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).

2.3 B



2.3C

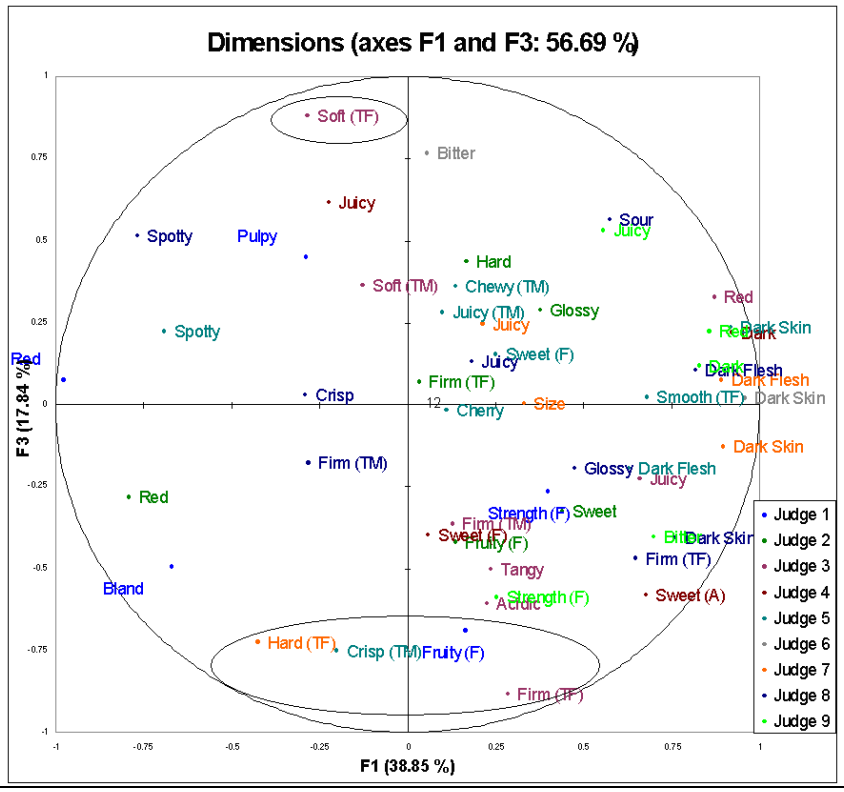
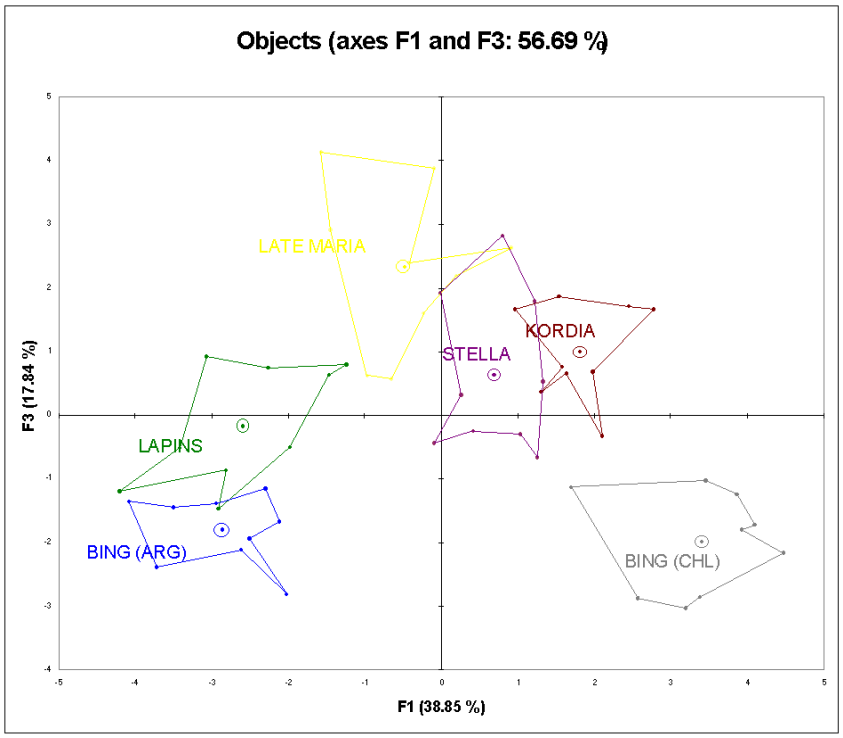


Figure 2.3: Plots of the GPA performed on the sensory data from the first evaluation session. (**C**) Variables plot determined by the first and third axis of the GPA. (**D**) Plot of the average configuration of samples determined by the first and third axis of the GPA (individual configurations superimposed).

2.3D



2.4A

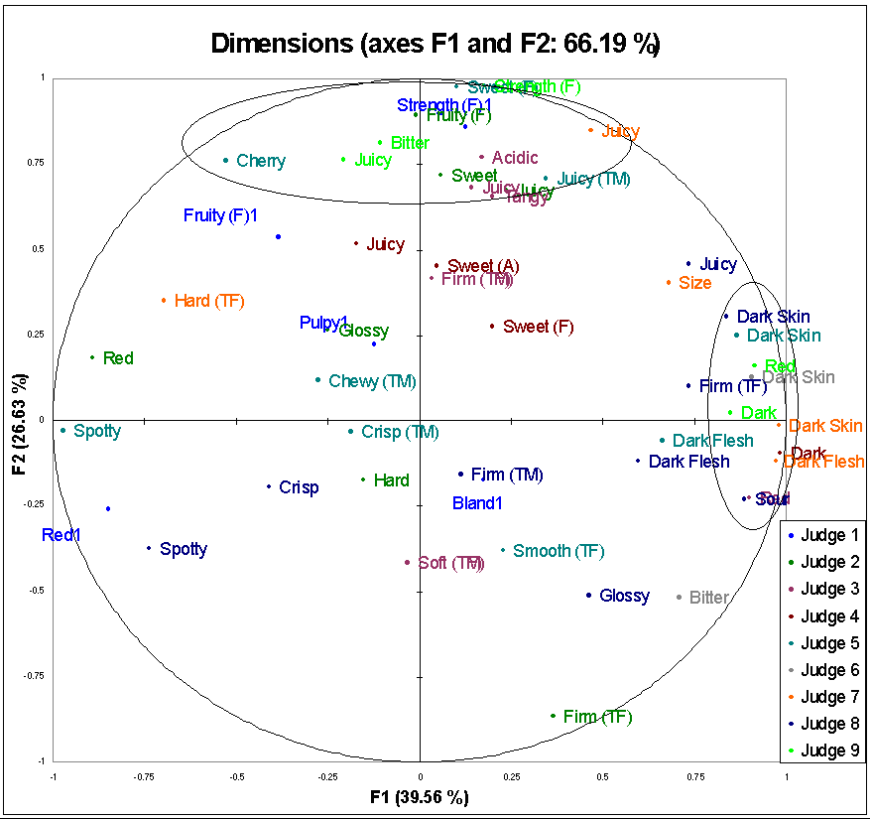
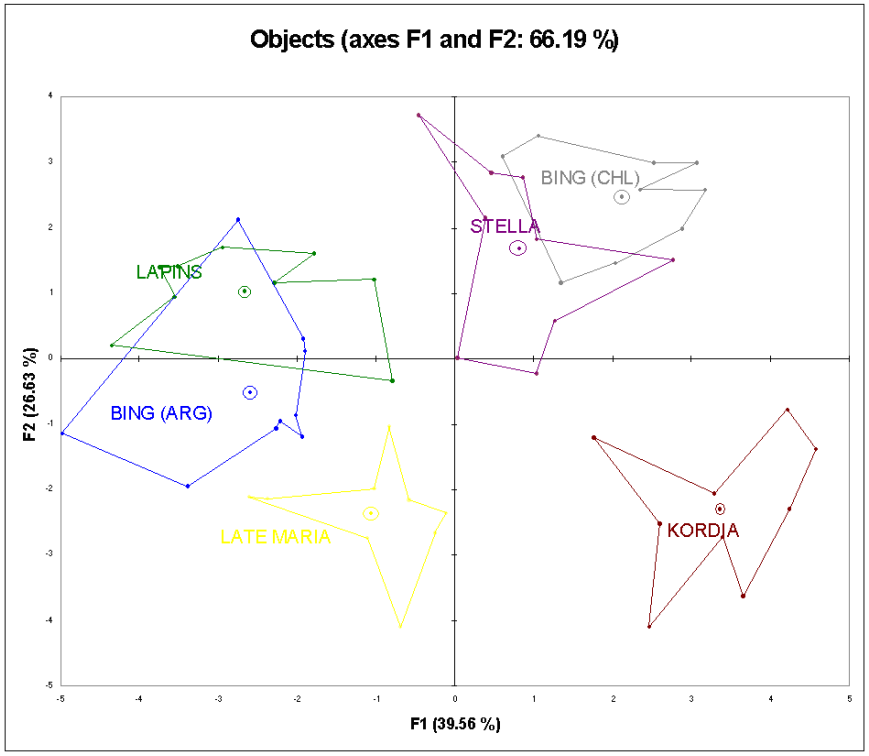


Figure 2.4: Plots of the GPA performed on the sensory data from the second evaluation session. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).

2.4B



2.4C

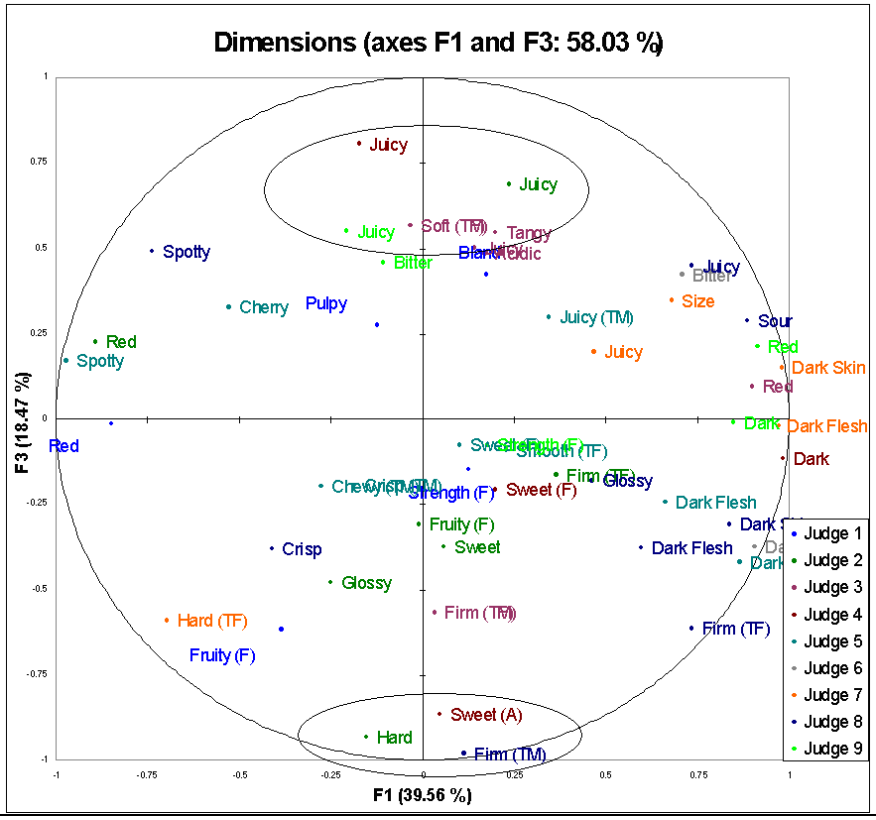
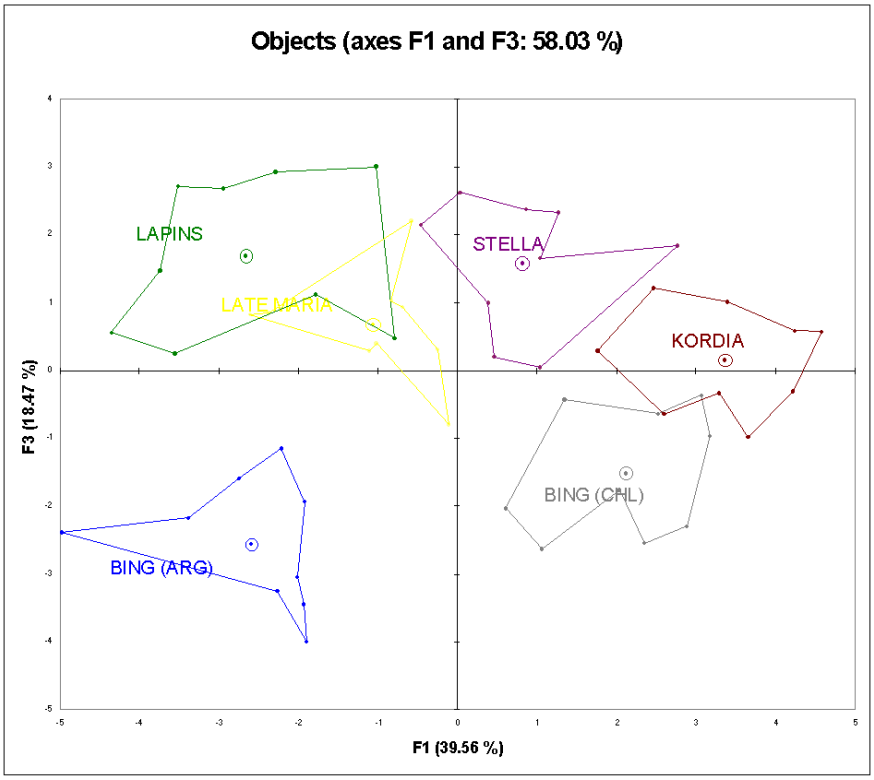


Figure 2.3: Plots of the GPA performed on the sensory data from the second evaluation session. (**C**) Variables plot determined by the first and third axis of the GPA. (**D**) Plot of the average configuration of samples determined by the first and third axis of the GPA (individual configurations superimposed).

2.4D



2.2.2.3. The relative sensory positioning of fresh sweet cherries

From the GPA plots of both evaluation sessions there appear to be 3 distinct groups defined by F1 (axis 1) based on colour of appearance. LAPINS and BING (ARG) both share a lighter red appearance, while STELLA and LATE MARIA have a much wider colour spread with some samples reported as light and others as dark whereas BING (CHL) and KORDIA and characterised by a much darker appearance than the rest.

F2 from both evaluation sessions is defined by flavour and the plots display grouping of similar products. LAPINS, STELLA and BING (CHL) appear to have more flavour than BING (ARG), LATE MARIA and KORDIA as all the consensus points of the first group lie in the positive region and all those in the latter lie in the negative region. All products with the exception of the two BING varieties lie in similar positions suggesting that there is a level of repeatability displayed by the judges between the evaluation sessions and that these samples were inconsistent. From the first evaluation session BING (ARG) is clearly negative in its F2 value whereas BING (CHL) is 50:50 with a spread of negative and positive values. In the second evaluation session there is a positive shift in scores of Bing suggesting a perception of a stronger flavour in this session. This was seen on the charts with BING (ARG) moving from the negative region to spread across both positive and negative values and the formerly 'borderline' BING (CHL) now scored as the sample with the most flavour.

From the GPA plots of both evaluation sessions there appears to be 3 distinct groups defined by F3 (axis 3) based on positive values implying soft and juicy texture and negative values implying firm and hard. Both Bing varieties display a spread of distinctly negative values in the two evaluation sessions, suggesting that this variety is particularly firm and lacks juiciness. While STELLA and LATE MARIA have a much more positive spread of scores suggesting a soft juicy character compared to Bing. LAPINS and KORDIA form the third group wit h a character that is not as well defined as the others. In the first session LAPINS showed a borderline spread of positive and negative scores suggesting some inconsistency whereas KORDIA was clearly positive. The reverse was seen in the second evaluation session, KORDIA borderline and LAPINS positive. This group is a characterised by inconsistencies in texture with some cherries being hard and firm but the majority are soft and juicy.

2.2.3. Discussion

After assessing the data from each session independently it is clear to see that the axes formed by Factors 1, 2 and 3 are characterised by the same attributes assessed in both evaluations. The Spearmann correlation co-efficient equation tests whether judges are significantly reproducible in their ratings of the cherry products. As mentioned earlier in Chapter 2.2.2.1 'Validation of the assessment of each judge: repeatability and discrimination ability' the Spearmann results suggested no significant correlations between the two evaluation sessions implying that judges were not reproducible and the data should be treated independently, creating separate plots for the two sessions. However the lack of significance observed following the Spearman tests suggested a lack of judge repeatability or consistency but this is more likely due to intra-variation and inconsistencies within a single cherry sample. Both charts were considered to have a similar meaning in terms of what the axes were expressing so GPA plots were created displaying F1, 2 and 3 from the combined data set (Fig. 2.5). The advantage of these plots (Fig. 2.5) is that the relative sensory position of the products can be seen as an average of both sessions on one chart rather than having to glance at the two plots from the two evaluation sessions and compare and contrast product positioning and create an average from them.

F1 separates the product set into two distinct groups based on colour with LAPINS, BING (ARG) and LATE MARIA forming the light red group and STELLA, BING (CHL) and KORDIA forming a darker red group. F2 separates the product set into two distinct groups comprising of different cherries to the groups observed in F1. It appears that the first group of LAPINS, STELLA and BING (CHL) have plenty of flavour and that the second group of BING (ARG), LATE MARIA and KORDIA are characterised by a lack of flavour. F3 also separates the product set into two groups with both BING varieties showing a harder or firmer texture than the rest which are discriminated from the BING varieties by their softer and juicer texture. A summary of the characteristics displayed by each product relative to the average of the whole product set can be seen in Table 2.5.

2.5 A

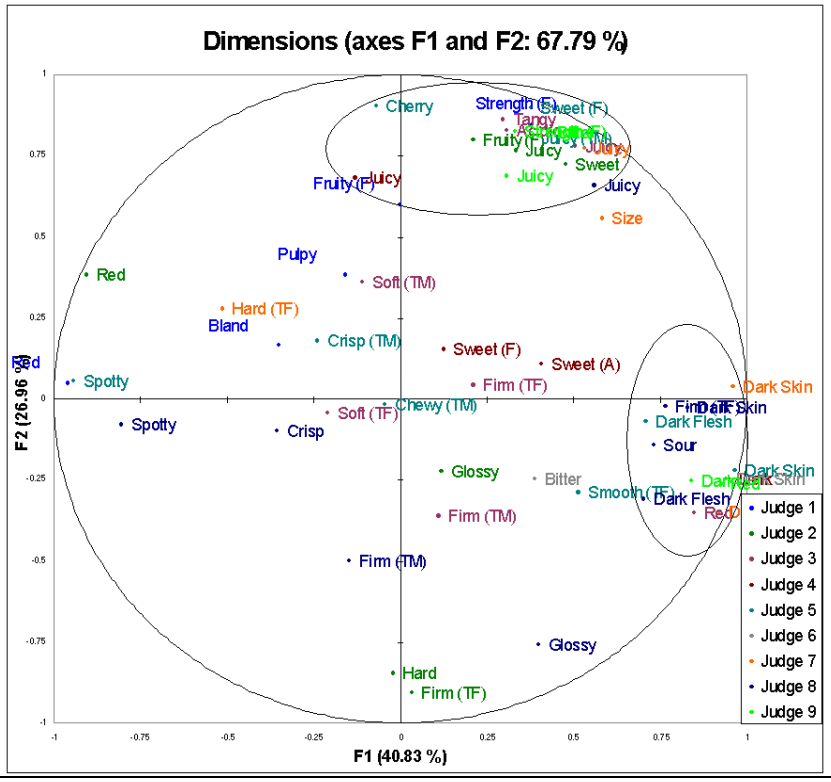
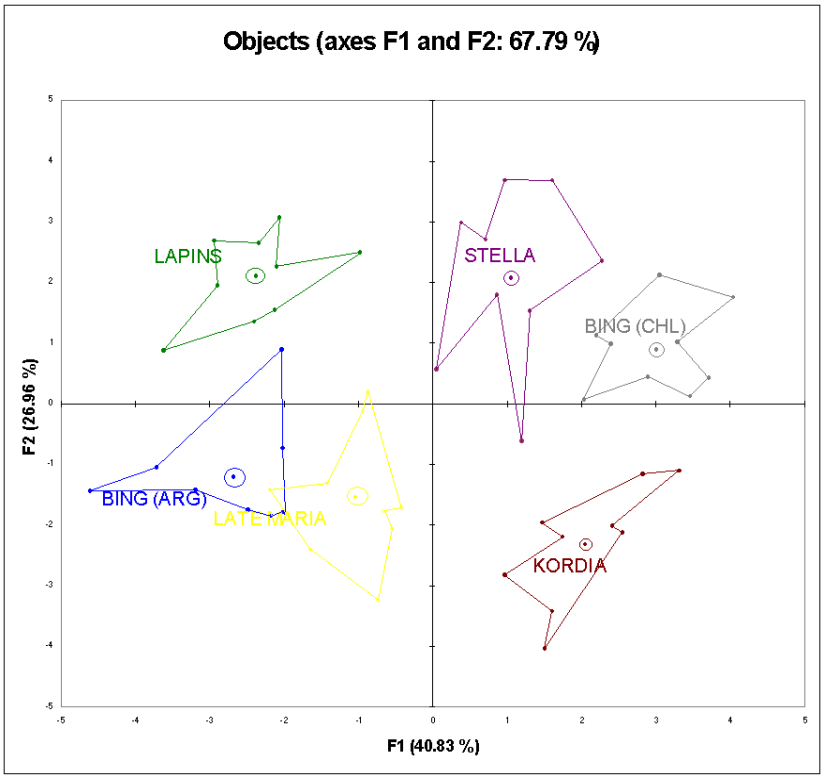


Figure 2.5: Plots of the GPA performed on the sensory data from the second evaluation session. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).

2.5 B



2.5C

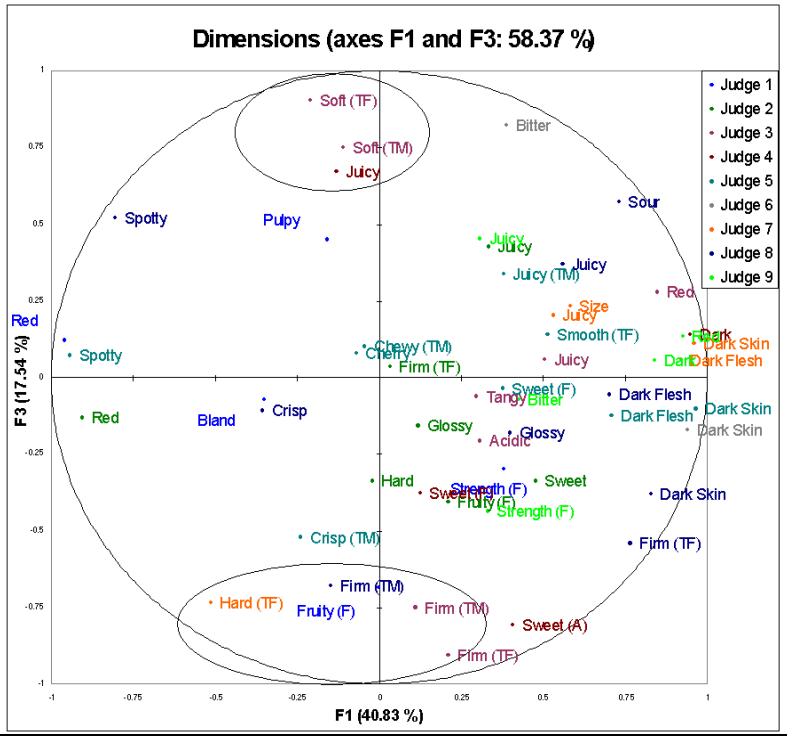


Figure 2: Plots of the GPA performed on the sensory data from the second evaluation session. (**C**) Variables plot determined by the first and third axis of the GPA. (**D**) Plot of the average configuration of samples determined by the first and third axis of the GPA (individual configurations superimposed).

2.5D

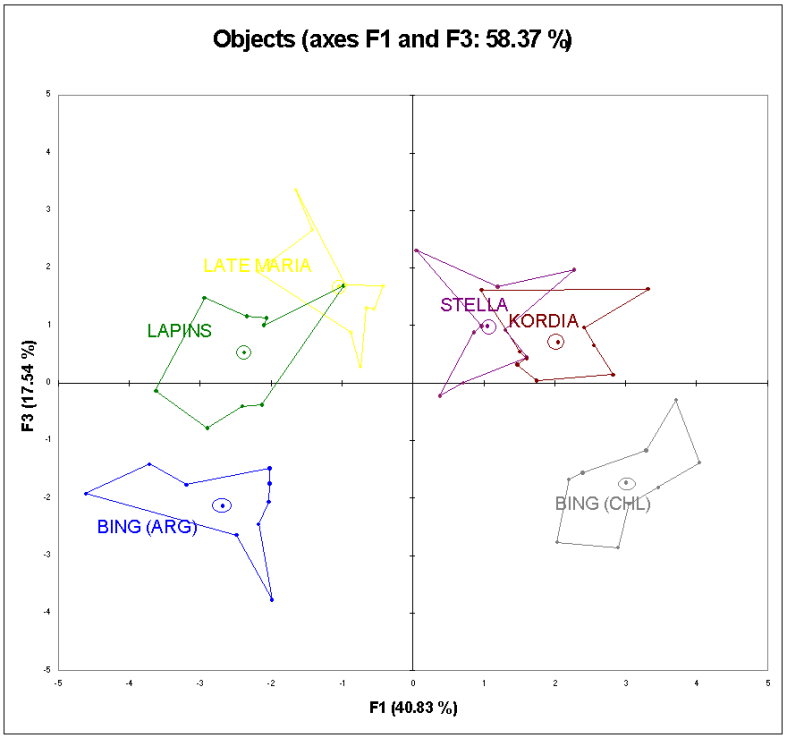


Table 2.5: The characteristics displayed by the corresponding factors viewed product-by-product in relation to the average of the whole product set.

Cherry ID	F1 Colour	F2 Flavour Intensity	F3 Texture
BING (ARG)	Light	Bland	Hard/Firm
LAPINS	Light	Flavoursome	Soft/Juicy
STELLA	Dark	Flavoursome	Soft/Juicy
KORDIA	Dark	Bland	Soft/Juicy
LATE MARIA	Light	Bland	Soft/Juicy
BING (CHL)	Dark	Flavoursome	Hard/Firm

This Flash Profile experiment differed to the previous one in that the 6 products selected for the experiment were considered by the cherry experts at Norton Folgate to have distinct differences and very few similarities, which would hopefully lead to further discrimination by the GPA plots to that seen in the previous Flash Profile. This proved to be the case as there was almost a complete separation of the products in the product space defined by factors 1 and 2 on the GPA plot of the combined data set (2.5B) and a lot less overlapping of product spaces to that seen in the first experiment.

3. Northern Hemisphere Season

The aim of this northern hemisphere season was to determine what the underlying key drivers of consumer liking were and this was to be achieved using the Flash Profile method, combined with an internal preference map. The idea behind combining the data was that the preference map would identify which products were liked by consumers and the flash profile would provide a description of those products uncovering what characteristics were driving the liking. An initial experiment was also undertaken prior to this final experiment to assess the integrity of the Flash Profile against analytical flavour analysis data to see whether the two data sets would support or contradict each other.

3.1. Flash Profile Using 6 samples

Different sample sizes of products were used in the two southern hemisphere experiments, eight and six respectively and this range was considered the optimum sample size to generate viable data which could be interpreted and assessed. For this experiment only two varieties of cherry were available, Ferrovia and Bing, but six samples were generated from these two varieties based on the farms from which they had originated. So, for this experiment, the cherry samples are distinguished not by variety but by farm origin.

Panel recruitment was also carefully considered as these Northern Hemisphere experiments were to generate results most significant to the commercial sponsor of the project (Norton Folgate Ltd.) and form the main body of the project. There was no need to screen assessors for the experiment as the panel did not need to be trained for consensual meaning of attributes describing cherries for this technique, they did however require previous experience with sensory testing (Dairou & Sieffermann, 2002). The University of Nottingham have a pool of 26 trained assessors (ISO 8586-1:1993) and of them 13 were selected for the test based on their availability at the time the study was taking place. Using 13 assessors where the previous experiments had used 9 was due to the loss of judges observed in the previous experiments when some of the judges were unable to significantly perceive any differences between samples (tested by ANOVA) or when the differences they perceived were not

correlated to the factors displayed by the plots. Hopefully at least 9 judges would significantly perceive differences between the samples and so the GPA plots would be generated with contributions from at least 9 judges. 13 judges were considered to be the maximum number required as co-ordinating more than 13 panellists would prove to be difficult over the 5 day period the cherries were to be tested. The five day or one working week restriction for completion of the Flash Profile experiment was imposed by the 6 day shelf-life of the cherries, beyond this the products may deteriorate and the profile may not be a true reflection of the cherries retailed by producers to the consumers. In addition, the size of the sensory science centre at the University of Nottingham needed to be taken into account as there were only 12 permanent and an additional 2 temporary booths available at any one time and the cost of a panel greater than 13 would have been excessive.

Individual sample size was also modified from the previous experiment as verbal feed-back from the panellists participating in the previous experiment believed that with 4 cherries per sample it was difficult to form an average of that individual sample and they suggested 3 cherries per sample would be better.

3.1.1. Methods

3.1.1.1. Selection of the sweet cherry samples

6 samples of cherry were imported to the U.K. by Norton Folgate Ltd. and sent to the University of Nottingham's School of Biosciences, Sutton Bonington. The 2 samples of the variety Ferrovia originated from Italy and the remaining 4 samples of the variety Bing were sourced from U.S.A. The samples were selected to reflect the time/age of cherries since harvest normally retailed by the producers to the consumers.

3.1.1.2. Sensory Panel

A panel of 13 judges, 3 men and 10 women, aged from 44 to 67 years were recruited for their experience in sensory analysis methodology, through participating in other sensory tests prior to this one. Previous sensory testing experience was required to generate original attributes for the description and discrimination of the

products. Ethical approval from the University of Nottingham ethics committee for the use of human subjects in these experiments was not pursued as it was deemed unnecessary as the products had not undergone any preparation, modification or manipulation and they were 100% natural.

3.1.1.3. Sensory Evaluation

Refer to Chapter 2.1.1.3 – but note where 8 samples are stated only 6 were used in this experiment. Also the evaluation sessions were twice as long because the external panel were available for up to three hours for each daily session and so they were encouraged to take their time and assess only one attribute each time they entered the booths. Occasionally two attributes were assessed, when time was limited, where-by assessing an appearance attribute such as size did not involve consuming the cherries and so the palate would not suffer fatigue prior to them moving on to assess a Flavour/Taste immediately after without a break.

3.1.1.4. Protocol for Sample Presentation

Refer to Chapter 2.1.1.4 – but note where 8 samples are stated only 6 were used in this experiment and each individual sample consisted of only 3 whole cherries not 4.

3.1.1.5. Statistical processing of Flash Profile data

Refer to Chapter 2.1.1.5

3.1.2. Results

3.1.2.1. Validation of the assessment of each judge: repeatability and discrimination ability

The repeatability of the judges between the two evaluation sessions was tested by the Spearmann correlation co-efficient test (data not shown). An attribute is considered as repeatable if the evaluated attribute from both the first and second evaluation session

are significantly correlated, at a significance level of $p<0.05$. Judge 3 was the most reproducible with 3 attributes out of the 10 generated and judge 9 was reproducible for 3 attributes out of 11 generated. The least reproducible judges were judges 11 and 13 both with 0 attributes from 10 generated. Of the repeatable attributes generated all but three were associated with appearance particularly colour and size, the other three being 'Bitter', 'Bitterness' and 'Flavour (Intensity)'. Only the reproducible attributes should be used to generate the GPA plots as defined by the original Flash Profile method (Dairou & Sieffermann, 2002) however as defined in the previous experiments the repeatability is distorted by the natural variation in the product. In the previous experiments this problem was overcome by producing separate GPA plots for each evaluation session and comparisons were made between the two plots. It was also noted in the previous experiments that although the SCC did not validate the repeatability the two prime factors of variation displayed in the plots from both sessions on observation were characterised by the same attributes and the products were mapped in relatively similar positions suggesting there was some repeatability.

This also proved to be the case for this experiment the two prime factors from both sessions were characterised by nearly almost all of the same attributes and the relative positioning of the products was almost identical. So the two sets of data from each evaluation session were combined to produce a single plot based on the mean average rank scores from the two sessions. The discriminant ability of the judges for each attribute was analysed using a one way ANOVA (Table 3.1), only the attributes considered significant were used to generate the GPA plot.

Table 3.1: F-value from ANOVA on sensory attributes of each judge of Flash Profile

*p<0.1, **p<0.05 and ***p<0.01 ****p<0.001

Judge 1	F-value	Judge 2	F-value	Judge 3	F-value
Shiny	5.78**	Red Skin	6.69**	Colour Of Skin	30.96****
Black	78.00****	Size	31.92****	Firmness	3.04
Red	9.52***	Shiny Inside Flesh	2.40	Flesh Firmness (Tm)	2.43
Frosted Skin	6.13**	Colour	9.3***	Juicy	3.53*
Deep Blood Red	159.60****	Sweet	1.860	Shiny	21.09****
Firmness (TF)	2.29	Sour	0.93	Sweet	0.51
Spongy/Soft (TF)	0.69	Juicy	4.07*	Aroma	2.57
Rubbery Skin	1.55	Fleshy Tm	1.52	Colour Inside	17.66***
Firmness (Tm)	1.28	Appearance	10.46***	Flavour	0.71
Crunchy Skin/Flesh	0.81	Fruity (A)	2.08	Size	10.46***
Powdery	0.530	Skin (Tm)	2.48		
Sweet	1.45				
Astringent	2.07				
Juicy	0.73				

Judge 4	F-value	Judge 5	F-value	Judge 6	F-value
Red Colour	161.70****	Colour Outside	7.20**	Colour	40.80****
Firmness	3.47*	Firmness	1.01	Size	9.30***
Size	5.80**	Juiciness	7.20**	Firmness (TF)	0.94
Tartness	1.01	Sharp	3.00	Cherry Flavour	7.39**
Bitterness	40.80****	Crunchy	1.27	Juiciness	0.63
Flesh	0.15	Colour Inside	10.46***	Grassy/Green (A)	0.98
Sweetness	4.8**	Sweetness	1.01	Sweetness	4.14*
Juiciness	0.63	Toughness of Skin	0.90	Tartness	10.46***
Cherry Flavour	7.20**	Bitter	0.75	Firmness (Tm)	5.42**
Skin	0.41			Bitter	159.60****
				Skin Toughness	2.15

Judge 7	F-value	Judge 8	F-value	Judge 9	F-value
Size	38.40****	Colour Outside	4.14*	Skin Colour	9.30***
Skin Colour	161.70****	Size	5.60**	Size	12.80***
Acidity	4.51**	Firmness	0.74	Soft (TF)	1.43
Juiciness	2.06	Colour Inside	9.30***	Sweetness	2.63
Sweetness	0.43	Juiciness	3.47*	Inside Colour	40.80****
Softness	3.28*	Sweetness	2.03	Skin (Tm)	2.03
Cherry Flavour	4.51**	Acidity	4.80**	Juiciness	4.05*
Flesh Colour	4.80**	Cherry Flavour	7.20**	Cherry From Stone	12.80***
				Lingering Taste	4.80**
				Depth Of Flesh	4.80**
				Biting to Swallow Time	5.42**

Judge 10	F-value	Judge 11	F-value	Judge 12	F-value
Colour	2.30	Colour Of Skin	6.84*	Intensity of Skin Colour	3.10
Firm (TF)	2.62	Juicy	1.72	Firmness (TF)	0.95
Firm (Tm)	0.16	Flavour	5.80**	Sweetness	0.28
Flavour	19.80****	Sharp	4.80**	Colour Of Flesh	31.92****
Inside Colour	31.92****	Firmness (TF)	1.85	Juiciness	0.89
Size	5.43**	Colour Of Flesh	5.43**	Firmness (TM)	0.63
Sweetness	5.80**	Thickness of Skin	1.39	Acidity	0.04
Acidity	2.62	Flesh coming away from stone	0.44	Eveness Of Skin Colour	5.43**
Depth of Flesh	3.33*	Texture in mouth	3.00		
Flesh left on stone	0.42	Sweetness	1.01		

Judge 13	F-value
Colour	4.71**
Firm (TF)	2.99
Texture in mouth	0.84
Colour Inside	10.80***
Juiciness	3.28*
Sweet	0.18
Stone Size	2.89
Size	2.84
Uniformity of colour	1.31
Sharp	0.72

3.1.2.2. Diversity of the attributes generated and used by the panel

Each of the 13 judges generated 8-14 attributes for a total of 130 attributes. The list of attributes generated and the frequency with which they were used by the panel is summarised in the Table 3.2. Sweet/Sweetness and Juicy/Juiciness were the most popular attributes with all judges selecting the first and all but one judge selecting the latter. Other popular attributes included those related to colour, size, firmness and flavour intensity with over half the judges selecting and assessing these attributes.

From the GPA performed on the data it appears that there are 2 factors accounting for 89% of the total variation between the products from the whole set of samples (Fig 3.1). Factors 1 and 2 accounted for 76% and 13% respectively of the total variation perceived within the product set. The GPA plot of F1 Vs F2 (Fig 3.1A) displaying 89% of the total variation showed that some attributes have a similar meaning for the different judges. On observation of the GPA plot, F1 Vs F2 from the combined evaluation sessions axis 1 appears to define colour of appearance and flavour intensity. All but one of the judges assessing colour of appearance seem to have a similar perception of the attribute ranking shades of cherry from light to dark with the exception of Judge 1 who assesses the attribute red on the cherries brightness and uses the attribute black to measure darkness. This can be seen on the plot with all attributes associated with colour or more specifically darkness of colour highly correlated to the positive part of axis 1 and yet the perception of red to Judge 1 who assessed red on the basis of brightness can be seen highly correlated in almost the exact opposite space of the plot in the negative part of axis 1. It appears that axis 1 is heavily influenced by colour due to the high correlations displayed by attributes associated with this and as you move from the negative region to the positive region the cherries appear to display a progressively darker red appearance. Not only is axis 1 influenced by colour of appearance but it also seems to be influenced by an intensity of flavours. Colour is clearly the dominant of the two with 24 attributes closely

Table 3.2: List of attributes generated and used by the panel for the Flash Profile

Modality/Attribute	Number of Judges using the same attribute
Appearance	
Shiny	3
Black	1
Red / Red Skin / Red Colour	3
Frosted Skin	1
Deep Blood Red	1
Size	9
Inside Flesh Colour / Colour Inside / Flesh Colour / Inside Colour	10
Appearance	1
Colour Of Skin / Colour / Skin Colour	7
Colour Outside	2
Cherry From Stone	2
Depth Of Flesh	2
Flesh left on stone	1
Thickness of Skin	1
Intensity of Skin Colour	1
Eveness Of Skin Colour	1
Stone Size	1
Uniformity of colour	1
Texture In Fingers	
Firmness (TF)	8
Spongy/Soft (TF)	2
Rubbery Skin	1
Softness	1
Texture In Mouth	
Firmness (Tm)	6
Crunchy Skin/Flesh / Crunchy	2
Powdery	1
Astringent	1
Juicy/Juiciness	12
Fleshy/Flesh Firmness/Flesh	3
Skin (TM)/Toughness of Skin/Skin Toughness	5
Biting to Swallow Time	1
Texture in mouth	2
Aroma	
Fruity (A)	1
Aroma	1
Grassy/Green (A)	1
Flavour	
Sweet/Sweetness	13
Sour	1
Flavour/Cherry Flavour	7
Tartness	2
Bitterness/Bitter	3
Sharp	3
Acidity	4
Lingering Taste	1

correlated to this axis but various descriptive flavour attributes combining to a total of 10 also seem to correlate to the positive region of this axis. The GPA plots display a couple of bitter attributes in the negative region of axis 1 with the rest of the flavour attributes such as acidity, tartness, sweetness and cherry flavour (×4) are all closely correlated to the positive region. On observation of the cherry samples prior to testing I believe that colour would certainly separate the two varieties Ferrovia and Bing but within a variety the colour was very similar and I believe what is separating the samples within a single variety on the GPA plot is these various flavour characteristics.

Most of the size attributes appear to be lying in the positive quadrant of both axis 1 and 2 but there is much closer correlation to the second axis than the first. This close correlation to axis two suggests that it defines size of cherries but with a slight clockwise skew, with negative values implying the cherry samples are smaller than the average seen in the product set and positive values implying they are larger.

3.1.2.3. The relative sensory positioning of fresh sweet cherries

The GPA plot of the combined evaluation sessions discriminates the two varieties based on colour of appearance, the two Ferrovia samples (Puglia & Simone) are clearly distinguished by their bright/light red appearance from the darker variety that is Bing. Three samples of the Bing variety (Delta Fresh, Morada and Sweet Treat) consistently display the darker colour of appearance and more intense flavour with every aspect of their positioning placed in the positive darker region, whereas Lodi Gold appears to be more variable and is arguably the lightest and least flavour intense of the four Bing cherry samples. That said, it still displays a darker characteristic in appearance than the two Ferrovia as seen on the plot by the physical separation and absence of any overlapping. Delta Fresh, on observation of the plots, was perceived to have the most intense flavour and darkest appearance of the Bing varieties of cherry and also considered by most judges to be the darkest most flavoursome cherry within the whole product set. Sweet Treat and Morada were difficult to distinguish solely by their colour and flavour intensity as there was a large region of overlapping on the plot. Delta Fresh was perceived by the majority of the panel to have the most intense flavour and darkest colour of the Bing varieties and Lodi Gold the least.

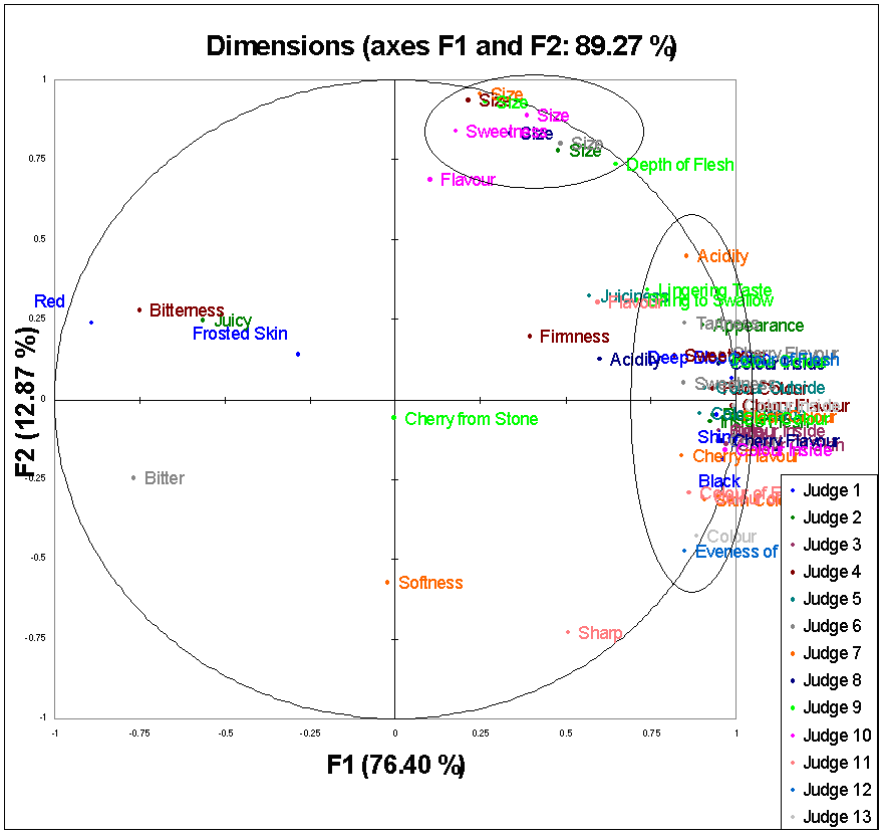
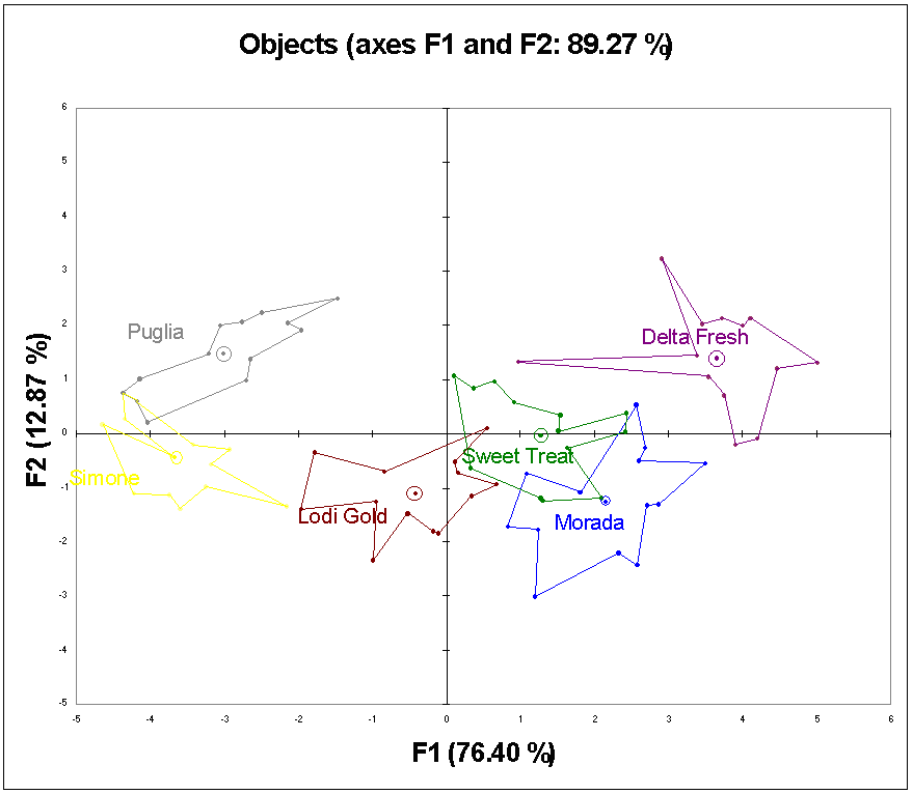


Figure 3.1: Plots of the GPA performed on the sensory data from the evaluation sessions combined. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).



Factor 2 provides further discrimination of the samples particularly the two Ferrovia samples as they share a similar product space in terms of their colour of appearance on axis 1 but the Puglia sample contained cherries of a larger size than that of the Ferrovia from the Simone orchards indicated by their separation on axis 2. Of the Bing varieties, Delta Fresh was perceived by the Judges to consist of the larger cherries whereas Lodi Gold, Sweet Treat and Morada were all of a similar sizing slightly smaller than the average seen in the whole product set. Sweet Treat could arguably be considered as the largest of the three in that group as there is some overlapping but 6 or 7 Judge's perceptions were that they appeared larger than the other two.

The descriptions of the cherries above, drawn from the judges perceptions displayed in the GPA plots match the descriptions defined by Bargioni (1996):
Bing – red-black skin, sweet very flavourful, aromatic and rich in soluble solids.
Ferrovia – bright red skin, very sweet and slightly acidic.

3.1.3. Discussion

The Flash Profile undertaken in Chapter 2.2 used 6 distinct varieties of cherry whereas this experiment comprised of only two varieties. So it was not surprising that there were only two significant factors accounting for most of the total variation where previously it had been three because it was evident that there was less variation present from my own observation of the samples prior to undertaking the Flash Profile. There was more overlapping of product spaces displayed in the GPA plot from this experiment but it was still able to clearly discriminate between the two varieties, Ferrovia and Bing, the overlapping was only observed within each variety. This showed that not only is the Flash Profile capable of discriminating cherry varieties but that it is also able to identify and pick out single varieties through grouping via the overlapping that was observed.

The GPA plots in this experiment were dominated by appearance particularly colour and size, so a GPA plot (see appendix) was created with appearance attributes removed to see if any other factors of perceived variation would emerge. Only one significant factor of variation emerged from the data when appearance was removed and this factor accounted for 85% of the total variation perceived across the product set. This factor was dominated by flavour attributes closely correlated to the negative

region of Factor 1 with an absence of attributes in the positive region with the exception of a couple of Bitter/Bitterness attributes. This suggested that axis 1 displayed a flavour intensity axis of greater intensity towards the negative region with a lower intensity towards the positive region. The attribute plot was clear in the perceived variation it was trying to define however the relative product positioning plot was not as clear. There was a large spread observed in each of the samples individual product spaces, there was much more overlapping than what had been witnessed in previous plots and there was also some clustering of the products close to and around the origin on the plot. There was very little to draw out of this plot as it was not clear to define the flavour intensity of the products. The only thing that could be taken from the plot was that Delta Fresh had a greater flavour intensity than Simone as they shared no overlapping of product space and the whole Delta Fresh product space lay in the negative intense flavour region of axis 1 whereas that of Simone lay entirely in the negative region, suggesting Delta Fresh had a more intense flavour than Simone. The other four sources of cherry displayed much more variation in their intensity of flavour and therefore could not be characterised solely on observation of this GPA plot.

3.2. Key Flavour Volatile and Non-Volatile Analysis

3.2.1. Raw Material

3.2.1.1. Selection of the sweet cherry samples

Refer to Chapter 3.1.1.1 – the cherries selected were those used in the Flash Profile described in Chapter 3.1.

3.2.1.2. Cutting Procedure

Each individual sample consisted of four cherries, and four repetitions of each sample were used to undertake the assessment. Each individual cherry was cut in half longitudinally using an aseptic (ethanol washed) sharp knife from stem end to the base down the pit and back up the anterior side. The two halves were then twisted and

pulled from the stone, one cherry half was retained for volatile analysis, the other for non-volatile analysis and the stone was discarded.

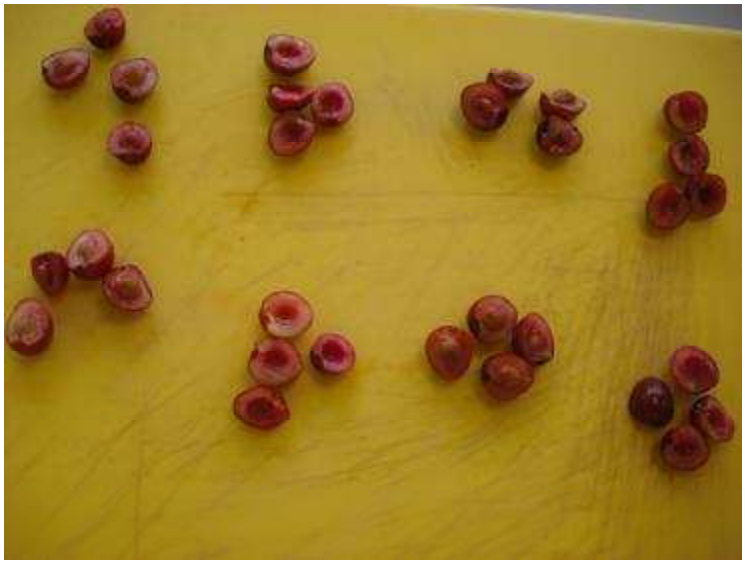


Figure 3.2: The raw cherry sample following the cutting procedure

3.2.2. Volatile Analysis Methods

3.2.2.1. Materials

3-heptanone (Aldrich, U.K.)

Methanol (Fisher Scientific, U.K.)

Calcium Chloride (Fisher Scientific, U.K.)

HPLC Fluorescence Grade Hexane (Fisher Scientific, U.K.)

3.2.2.2. Preparation of the Internal Standard

In order to quantify the volatile compounds it was necessary to prepare and add a known standard to the cherry samples. A primary solution was prepared in 10ml measuring flask containing 100µl of 3-heptanone topped up to 10ml with methanol. An aliquot (100µl) of the primary solution was then added to a second measuring flask and again topped up to 10ml with methanol to create the secondary solution. A 100µl portion of this second solution contained 10µg of 3-heptanone.

3.2.2.3. Solvent (hexane) Extraction of Volatile Compounds

Approximately 15g (four cherry halves) of sweet cherry tissue was homogenised with distilled water and a saturated $CaCl_2$ solution at a ratio 4:2:1. The water was added to reduce the viscosity of the homogenised cherry tissue samples permitting the solvent to mix through the sample and effectively extract the volatiles. The saturated $CaCl_2$ solution was added to reduce enzyme activity which could potentially alter the volatile profile of the sample.

Figure 3.3: Homogenisation of the cherry tissue in distilled water with the presence of $CaCl_2$

Following homogenisation 100µl of the internal standard containing 10µg was added to the sample prior to mixing and the area of the peak generated on the chromatogram from this known standard would be used to enable quantification of the target compounds. This was to be achieved by directly comparing the area of the peaks generated by the sample to the area of the standard. Hexane (4ml) was also added and the sample was then mixed for an hour (name of mixing equipment and speed it mixed at) to allow the hexane ample time to extract the volatiles.

The sample was then spun in JOUANE CR3i multifunction centrifuge (Thermo Electron Corporation, U.K.) at 2000rpm for 5 minutes at 25°C. The oil fraction containing the volatiles was skimmed from the top of the sample and placed in micro tubes compatible with the GC-MS auto sampler.

3.2.2.4. Gas Chromatography – Mass Spectrometry Analysis

The GC-MS consisted of a 'Trace GC Ultra' gas chromatograph (Thermo Electron Corporation, U.K.) and a 'DSQ' mass spectrometer (Thermo Electron Corporation, U.K) and samples were injected on to the column via a CTC Analytics auto-sampler. The auto-sampler injects the solvent sample into the injection inlet which evaporates the sample converting it to the gas phase before it is loaded on to the column. The column is then used to separate the volatiles based on their functional group and size. The most volatile compounds leave the stationary phase first and the least volatile compounds are retained in the stationary phase of the column for longer. The compounds then enter the source housing of the mass spectrometer where ionisation of the compounds takes place. This ionisation technique employed by the mass spectrometer uses positive chemical ionisation, which causes the compound to fragment prior to passing through the quadrapoles and hitting the detector. The detector picks up the fragments and each compound has a unique fragment pattern which determines the identity of the compound.

The settings of the gas chromatograph were as follows:

- Solvent sample volume: 2µl
- Carrier gas: Helium
- Carrier gas flow rate: 1ml.min^{-1}
- Carrier gas flow mode: constant flow
- Capillary column: ZB5 (Zebron™)
- Split flow (sample): 10ml.min^{-1}
- Temperature Settings

  Injection inlet: 250°C

  Start: 40°C (Hold time: 2 min)

  Ramp: 10°C.min^{-1}

  Terminal: 250°C (Hold time: 2 min)

The settings of the mass spectrometer were as follows:

- Ion source: positive chemical ionisation
- Ion source temperature: 200°C
- Detector gain: 1.00 × 1015 (Multiplier voltage: 1266 V)
- Scan mode: full scan

- Scan time: 0.39 secs
- Scans per second: 2.5461
- Scan rate: 571.7 (amu/s)

3.2.3. Non-Volatile Analysis Methods

To analyse the behaviour of the key non-volatiles of sweet cherry fruits three relatively simple measurements were undertaken: the volume of titratable acidity, the pH and the refractory index.

3.2.3.1. Titratable Acidity (TA) and pH

Freshly pressed cherry juice was extracted from the whole fruit samples and 1ml of this juice was added to 9ml of distilled water. The pH of this 1×10^{-1} dilution was recorded then titrated using a 0.1M NaOH solution to an end point of pH 8 and then expressed as percentage malic acid. The titration was performed using an auto-titrator combined with a pH meter (TTT80 auto-burette with PHM82 pH meter, Radiometer, Copenhagen) which mixes the sample as it reads, the advantage over static unmixed samples is that it settles quickly and generating a true pH measurement.

The TA expressed as percentage malic acid was calculated by the equation below:

TA= ml NaOH × N(NaOH) × acid meq.factor × 100ml juice titrated

3.2.3.2. Soluble Solids Content (SSC) – Refractive Index

Sugars are the primary soluble solid in cherry juice and therefore soluble solids can provide a quick reliable estimate of sugar content. Some organic acids, amino acids, phenolic compounds and soluble pectins can also contribute to the soluble solids content but it is still recognised commercially as the most practical indicator of sugar content. SSC can be determined using a relatively small sample of cherry juice placed on and covering a lens of a refactometer (ATAGO Pocket PAL-1, Tokyo) such as the one pictured below.

Figure 3.4: Digital refractometer

The refactometer measures the degree to which light bends as it passes through the sample and compares it to a standard of pure distilled water which sets the bending of light at zero prior to measuring the cherry juice samples. This bending of light also known as refractory index is expressed on a scale % Brix.

3.2.4. Results

3.2.4.1. Volatlies

After the injection in the GS/MS , the Xcalibur software was used to calculate the concentration of main volatile compounds.(see appendix 1)

Benzaldehyde has been considered as the primary contributor to the characteristic cherry flavour (Schmid & Grosch, 1986b) and originates from enzymatic hydrolysis of amygdalin in stone fruits or can be derived from precurseors such as phenylalalanine and benzyl alcohol (Nahrstedt,1972). C6 aldehydes, hexanal and *E*-2-hexenal are formed by the action of the lipoxygenase pathway on fatty acids with corresponding secondary compounds such as *E*-2-hexenol (Meheriuk *et al.,* 1995; Paillard and Rouri,1984) . C6 aldehydes are associated with green/grassy/herbaceous odour while (E)- hexenol exhibits a fruity/leafy/sweet/nutty odor (Paillard,1990; Fenaroli, 1979**).** Benzaldehyde is associated with sweet nutty/almond odours which is not surprising as it is also present in almonds (Schmid & Grosch 1986b).

Below is a list of retention times of the 3 main compounds associated with cherry flavour:

- hexanal 7.66.min
- *E*-2-hexenal 8.73min
- benzaldehyde 10.93min
- internal standard (3-heptanone) 9.35min

Among these compounds, the presence of *E*-2-hexenal is the largest in the cherry samples, followed by hexanal then benzaldehyde which is present in relatively smaller quantities (see appendix I).

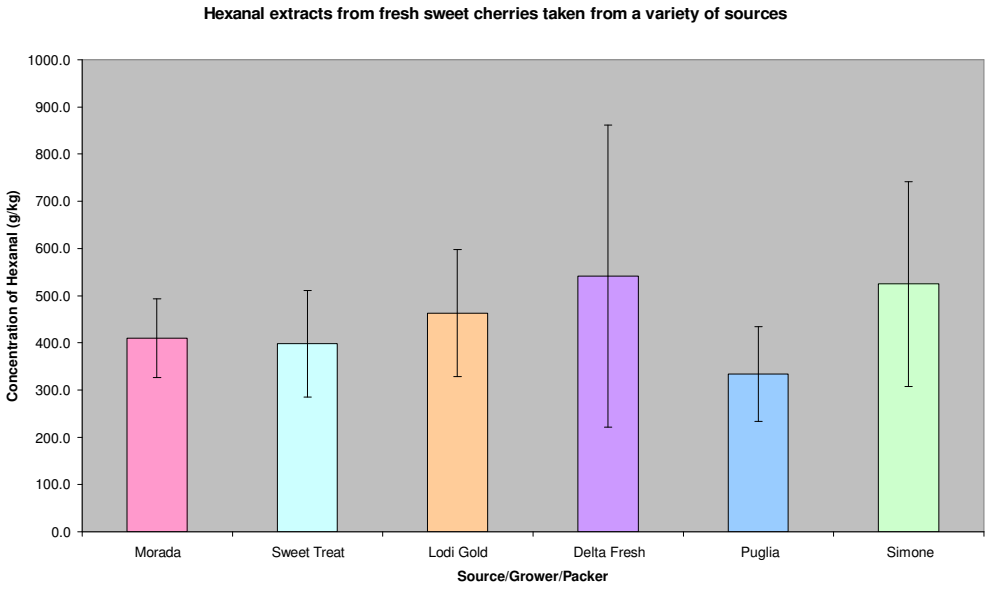


Figure 3.5: the average concentration of hexanal in fresh sweet cherries taken from various sources

There were no significant differences measured in the concentration of hexanal between the 6 sources of cherry (ANOVA data, see appendix I).Each source has a similar concentration of hexanal (Fig 3.5). Suggesting differences in flavour perception were not directly associated with the concentration of this compound.

There was a significant difference measured in the concentration of *E*-2-hexenal between the 6 samples of cherry (ANOVA data). Lodi Gold displayed a significantly higher concentration than the rest with the exception of Delta Fresh (Fig 3.6). However one the results from the four repetitions for Delta Fresh was lost during the experiment so it's mean and standard deviation are based on three results not four. The three results reported in Delta Fresh were more variable than the other cherry samples giving rise to a relatively large standard deviation which is why none of the other cherry samples displayed a significant difference to this sample.

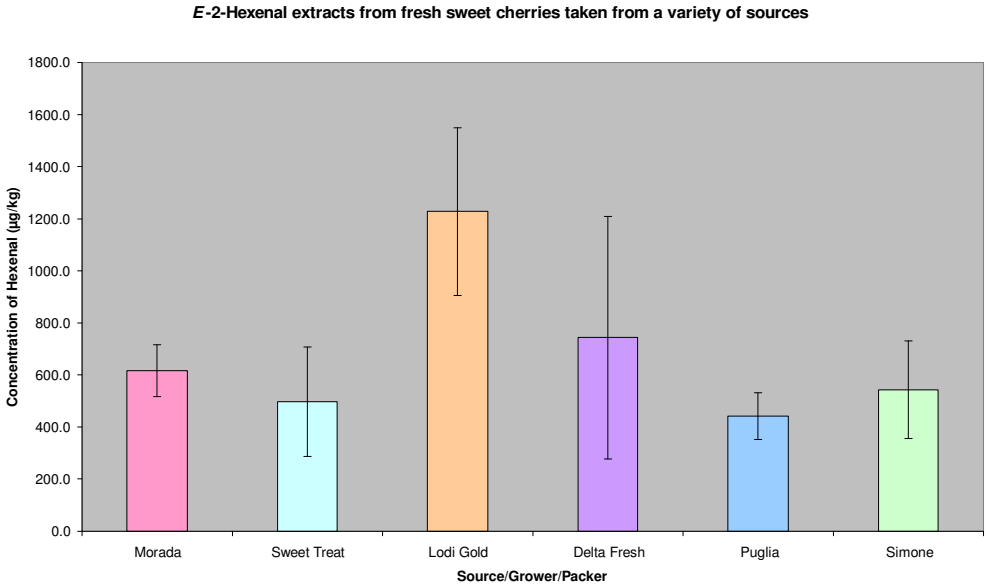


Figure 3.6: the average concentration of *E*-2-hexenal in fresh sweet cherries taken from various sources

There was a significant difference in the concentration of benzaldehyde measured between the 6 cherry samples (ANOVA data). Lodi Gold significantly displays the highest concentration of benzaldehyde content within the Bing variety and significantly more than both of the Ferrovia varieties (Fig 3.7). Simone contains a significantly greater concentration than Puglia within the Ferrovia variety.

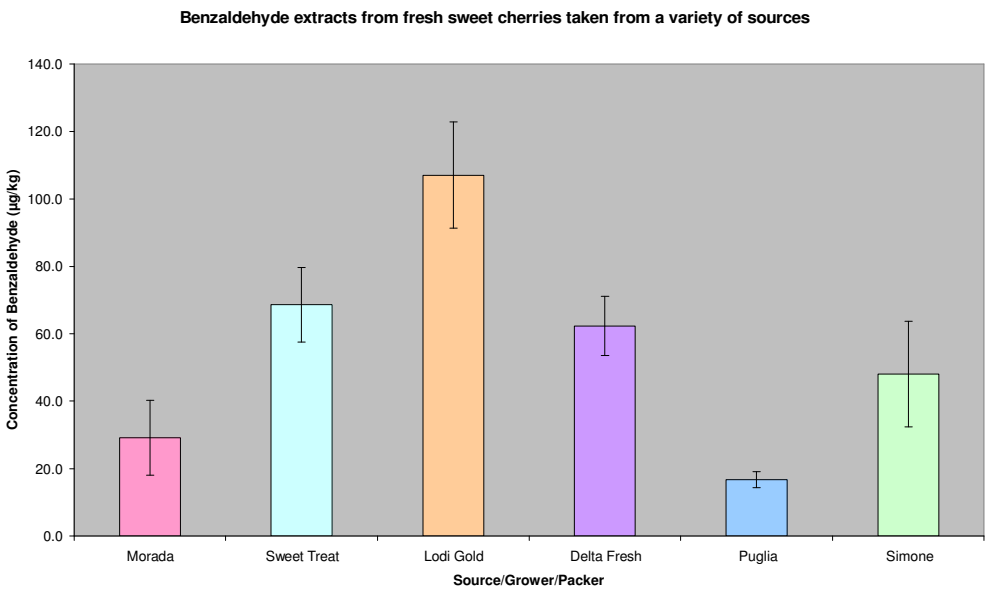


Figure 3.7: the average concentration of benzaldehyde in fresh sweet cherries taken from various sources

3.2.4.2. Non-Volatiles

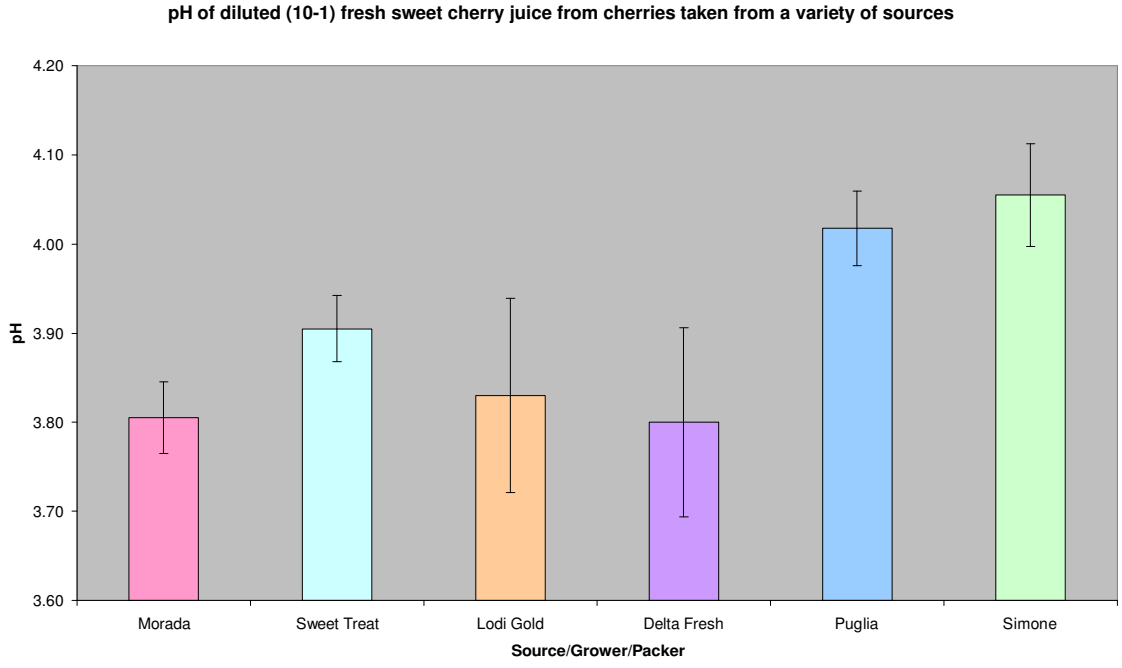


Figure 3.8: the mean average pH of diluted (1×10^{-1}) fresh sweet cherry juice taken from various sources of cherry

There was a significant difference in the pH of the cherry samples with the two Ferrovia varieties displaying a higher pH value than the Bing, with the exception of Sweet Treat whose pH lies between both the Bing and the Ferrovia varieties (Fig 3.8). This data suggests that the Bing variety has a higher relative acidity to that seen in the Ferrovia variety.

There was a significant difference in the % TA reported between the 6 cherry samples (Fig 3.9). Of the Bing varieties Morada and Delta Fresh displayed a significantly greater %TA than Sweet Treat, Lodi Gold and the two Ferrovia varieties. There was no significant difference reported between the two Ferrovia varieties regarding percentage of TA but on observation of Figure 8 Puglia displays a higher percentage of TA.

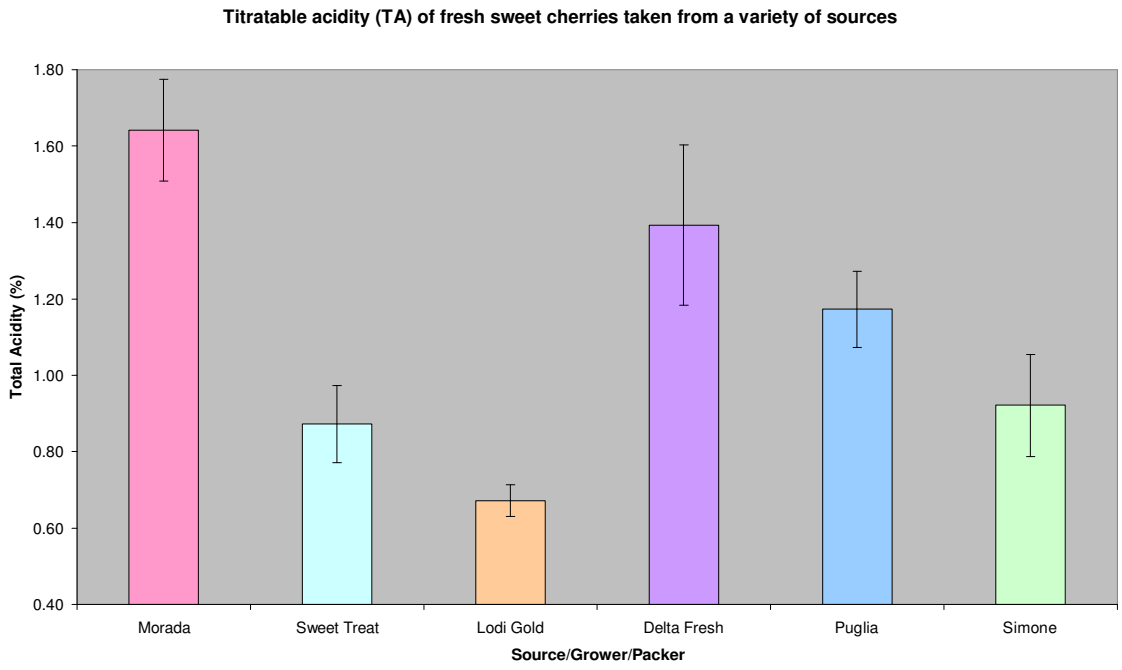


Figure 3.9: the mean average % TA of fresh cherry juice taken from various sources of cherry

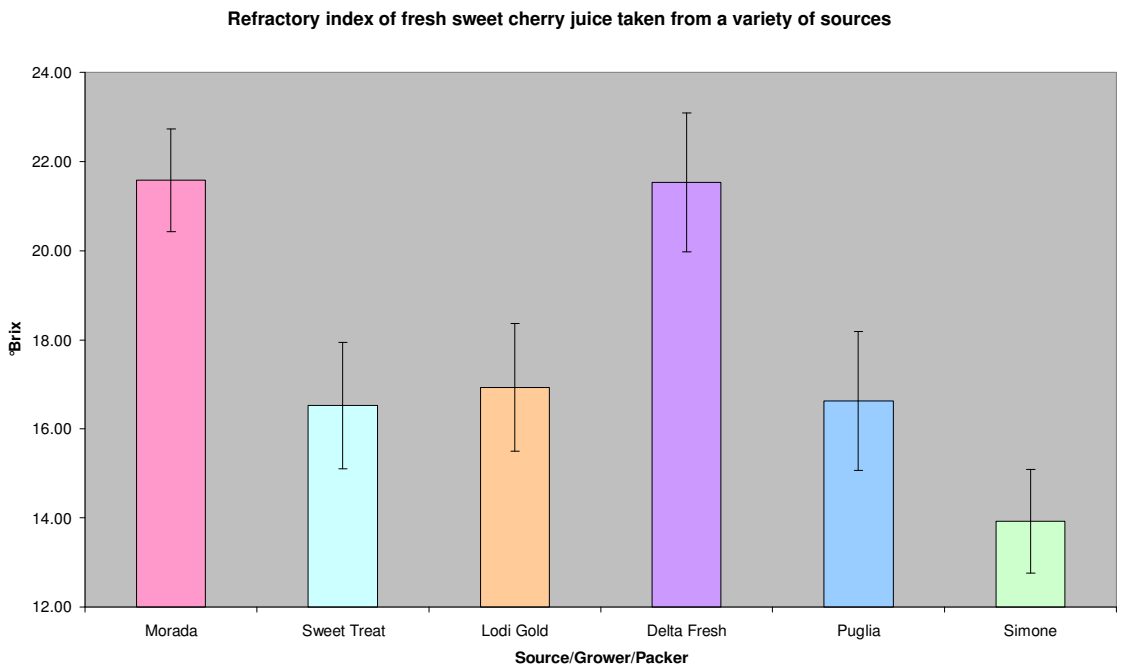


Figure 3.10: the mean average % brix of fresh sweet cherry juice taken from various sources of cherry

There was a significant difference in the refractory index reported across the 6 cherry samples (Fig 3.10). Morada and Delta Fresh displayed a significantly higher brix than the rest of the cherry samples, suggesting they may be much sweeter. Of the Ferrovia variety Puglia had significantly greater % brix than Simone and Simone had significantly the lowest brix within the whole cherry samples set.

3.2.5. Discussion

Mean average (*E*)-2-hexenal concentrations reported ranged from as low as 441.4µg/kg in the Ferrovia variety (Puglia) up to 1227.6µg/kg in the Bing variety (Lodi Gold). Experiments using GC-MS performed by others have reported ranges from as little as 21.1 - 692.9µg/kg across a range of sweet cherry varieties (Girard & Kopp, 1998) and as high as 1,075.2 - 2,229.0µg/kg in a single variety (Lapins) over a storage period of 10 weeks (Meheriuk *et al.*, 1995). In many of the experiments reported assessing volatiles of sweet cherries (either intact, destroyed or as juices) using GC-MS analysis (*E*)-2-hexenal was the most abundant and this was true to this experiment. Although not all the volatile compounds within the cherries were identified in this experiment, as the focus was on the three prime volatile contributors

(hexanal, (*E*)-2-hexenal and benzaldehyde) to sweet cherry aroma (Schmid & Grosch, 1986a), it was still identified as the largest peak from the chromatograms. This clearly supports the knowledge that (*E*)-2-hexenal is one of the prime contributors to cherry aroma as described by others working in this area (Schmid & Grosch, 1986b; Mattheis *et al.*, 1992a; Meheriuk *et al.*, 1995; Bernalte *et al.*, 1998; Girard & Kopp, 1998).

Previous experiments using GC-MS analysis reported ranges of hexanal concentrations in sweet cherries between 97.3 - 292.9µg/kg across a range of sweet cherry varieties (Girard & Kopp, 1998) and 299.2 - 556.4µg/kg in a single variety (Lapins) over a storage period of 10 weeks (Meheriuk *et al.*, 1995). The mean average hexanal concentrations reported in this experiment ranged from 333.7 - 542.1µg/kg which is relatively similar concentrations to those observed in the other experiments. As mentioned earlier there were no significant differences reported suggesting this is not a key factor directly responsible for differences in flavour intensity perception between varieties.

The benzaldehyde concentrations in measured in this experiment ranged between 16.7 - 107.1µg/kg whereas others reported ranges of 19.5 - 207.9µg/kg (Girard & Kopp, 1998) and 40.2 - 72.9µg/kg (Meheriuk *et al.*, 1995). Benzaldehyde was present in relatively lower concentrations to the two volatiles described above, but it is still considered to be just as prime a contributor to cherry aroma as the others. Benzaldehyde has a relatively lower detection threshold (Keith & Powers, 1968) than the other two, which means it can have just as big an impact as the other two volatile compounds even at lower concentrations and this could be due to a number of possible interactions with other composites in the cherry. Its perception could be enhanced (or similarly suppressed) by interactions due to the presence of other volatiles, non-volatiles or the physico-chemical structural properties of the cherry which determine its release during eating (Noble, 1996; Pfeiffer *et al.*, 2005).

The concentrations of the volatiles reported in this experiment were relatively similar to those in other experiments, but there were slight differences, this could have been due to the method of extraction and the settings and set-up of the GC-MS. The results of this experiment were obtained from a solvent extraction using hexane and have been comparable to experiments using a purge and trap headspace analysis of cherry comminute from a blender (Girard & Koppp, 1998; Meheriuk *et al.*, 1995).

Sweet cherries are considered to be a moderately acidic fruit with a juice pH of approximately 4.0 (Looney e*t al.*, 1996) and the values reported in this experiment supported this. There was a significant difference between the two varieties with the two Ferrovia varieties reporting a slightly higher pH than the Bing variety, with the exception of one Bing variety, Sweet Treat which lay between the two. The mean average pH reported in the Bing varieties were all < 4.00 and ranged from 3.80 - 3.91, while the values of Ferrovia were slightly >4.00, ranging from 4.02 - 4.06.

The mean average TA of the four Bing varieties reported in this experiment ranged from 0.67 – 1.64% whereas previously a range of 0.53 – 1.19% has been reported in a single Bing sample (originating from a similar region, California, U.S.A.) across a series of colour stages (Crisosto *et al.*, 2003). The mean average TA of the two Ferrovia varieties ranged from 0.92 - 1.17% and a previous experiment had reported a range of 0.67 – 0.81% of a single Ferrovia sample (originating from the same region, Puglia, Italy) over a storage period of 15 days (Esti *et al.*, 2002). The values reported in this experiment were similar to the values expected in sweet cherries but the values specific to each variety differed to those which had been reported previously as they generally displayed a higher TA value. One might expect them to be more similar, after all they have been grown in similar regions and therefore similar soil types to those previously reported but the weather and other factors can differ year by year producing a crop with variable TA levels and this variability can also affect other qualities, not just TA, it may alter refractive index as well. Wine is an indirect classic example of this, its quality changes year by year and this is related to the changes in grape quality due to variable weather during the growing season in the same vine-yard.

The mean average refractive index results reported ranged from 13.93 – 21.58%, with Bing ranging from 16.53 - 21.58% and Ferrovia 13.93 – 16.63%. Both ranges were almost within the ranges reported in previous experiments where similar varieties from similar regions had been assessed (Esti *et al.*, 2002; Crisosto, *et al.*, 2003). Of the cherry samples Morada and Delta Fresh had a significantly higher refractive index than the rest both reporting values >21% whereas the rest were all <17%.

It is interesting to see how this analytical data ties in with people's perceptions drawn out of the Flash Profile data. In the previous experiment (see chapter 3.1) the

prime factor of variation perceived by the panel was dominated by colour of appearance and this separated the two varieties Ferrovia and Bing, however, within a variety, there appeared to be further separation driven by flavour intensity. After assessing this data, it appears that the differences in perception of flavour intensity within a variety are driven by refractory index and TA. Both Morada and Delta Fresh displayed significantly higher values than their other Bing counter-parts regarding the analytical quality attributes and both seemed to be positioned towards a greater intensity of flavour on the GPA plots (the positive region in axis 1). A similar trend, although not as significant, was also seen in the Ferrovia variety. The positioning of Puglia lay in a slightly more positive region of axis 1 displaying a significantly greater TA than Simone and greater mean average refractive index (although not significant). It could also be argued that the perceived difference between Ferrovia and Bing was not solely driven by colour as there were significant differences in pH reported between them, with the exception of the one Bing variety Sweet Treat. Bing generally displayed a lower pH suggesting more acidity and hence a greater flavour intensity.

3.3. Flash Profile using 6 Varieties of Sweet Cherry

A selection of cherry varieties were chosen by Norton Folgate; the Flash Profile was to be applied to generate a description of this selection and a consumer study was to follow to see which of these cherries were liked and which were not. The consumer data was to show which cherries consumers preferred and the Flash Profile was to illustrate why.

3.3.1. Methods

3.3.1.1. Selection of the sweet cherry samples

3 samples of cherry sourced from the U.K and 3 samples were imported to the U.K. by Norton Folgate Ltd. and sent to the University of Nottingham's School of Biosciences, Sutton Bonington. The 6 samples consisted of 6 different varieties,

Colney, Stella and Regina originated from the U.K. whereas the Bing, Lapins and Picotta varieties originated from the U.S.A., Canada and Spain respectively. The samples were selected to reflect the time/age of cherries since harvest normally retailed by the producers to the consumers.

3.3.1.2. Sensory Panel

Refer to Chapter 3.1.1.2 – The same panel was used but with only 12 judges rather than 13 as one of the panellists was unavailable during the period in which the experiment was taking place. These 12 judges were already familiar with the Flash Profile technique and with time available for testing restricted to 1 week it was decided much more appropriate to use the same panel as they would not be prone to making mistakes regarding the instructions outlined to them.

3.3.1.3. Sensory Evaluation

The Flash Profile was performed using the procedure defined by Dairou & Sieffermann (2002). Assessments of each characteristic (attribute) chosen by each judge were performed in triplicate similar to the original (Dairou & Sieffermann, 2002) method, whereas the assessments in 3 previous Flash Profile experiments were performed in duplicate (Rason et al., 2006). The first session involved each judge individually generating their own list of descriptive terms. All 6 samples of sweet cherry were presented simultaneously and the terms were generated, then categorised as appearance, texture, aroma or flavour. The judges were asked to list the sensory attributes which were ideal for describing the differences they perceived between the sweet cherry samples and they were instructed to avoid hedonic terms. The length of this session averaged at approximately 30 min and ranged from 20-35 min. and between this first and the second session all the attributes generated by the panel were compiled in a list. At the beginning of the second session, judges were asked to read the panel's list and to update their own list if desired. The judges individually proceeded to the evaluation itself on a ranking mode where ties are allowed, using their own definitive list of terms. Six samples of cherry were presented simultaneously in a balanced randomised order for the judges to taste. Following first tastes of each sample judges were able to re-taste the sweet cherries as

much as they desired. Pauses of 10 minutes were given during the evaluation to avoid reduced sensitivity on the palate. The third and fourth sessions were replicates of the second session. The three evaluation sessions (sessions 2, 3 & 4) lasted approximately 120-135 minutes each and all sessions were conducted in standardised booths (ISO 8589:1988).

Data was collected manually with judges recording their responses to the first session in writing and the two subsequent sessions by ranking products on the blank scales provided. In order to uncover the true meaning of each description judges could use their own anchors for these scales if desired. An example of this was the attribute 'Red' where the judge responded with light and dark as anchors for the scale before ranking the products for this attribute. An example of the instructions and blank scales given to the panellists can be found in Appendix I

3.3.1.4. Protocol for Sample Presentation

Refer to Chapter 2.1.1.4 – but note where 8 samples are stated only 6 were used in this experiment and only 3 whole cherries per sample were presented to assessors.

3.3.1.5. Statistical processing of Flash Profile data

Refer to Chapter 2.1.1.5

3.3.2. Results

3.3.2.1. Validation of the assessment of each judge: repeatability and discrimination ability

The repeatability of the judges between the three evaluation sessions was tested by the Spearmann correlation co-efficient test (data not shown). An attribute is considered as repeatable if the evaluated attribute from both the first second and third evaluation session are significantly correlated, at a significance level of $p<0.05$. Judges 6 & 12 were the most reproducible with 4 attributes out of the 8 generated and judge 5 was reproducible for 4 attributes out of 10 generated. The least reproducible judge was judge 8 with 0 attributes from 8 generated. 29 of 107 attributes generated

were considered by the SCC to be repeatable and of these repeatable attributes 16 were associated with appearance, 8 with texture and 5 with flavour. Only the reproducible attributes should be used to generate the GPA plots as defined by the original Flash Profile method (Dairou & Sieffermann, 2002). However as defined in the previous experiments, the repeatability is distorted by the natural variation in the product. In the experiment defined in Chapter 2.1 this problem was overcome by producing separate GPA plots for each evaluation session and comparisons were made between the two plots. It was also noted in the previous Flash Profile experiments that although the SCC did not validate the repeatability the two prime factors of variation displayed in the plots from both sessions on observation were characterised by the same attributes and the products were mapped in relatively similar positions suggesting there was some repeatability.

This was assumed to be the case for this experiment i.e. that the two prime factors from both sessions would be characterised by nearly almost all of the same attributes and that the relative positioning of the products would be very similar. So the three sets of data from each evaluation session were combined to produce a single plot based on the mean average rank scores from the three sessions. The discriminant ability of the judges for each attribute was analysed using a one way ANOVA (Table 3.3), only the attributes considered significant were used to generate the GPA plot.

Table 3.3: F-value from ANOVA on sensory attributes of each judge of Flash Profile

*p<0.05, **p<0.01 and ***p<0.001

Judge 1	F-value	Judge 2	F-value	Judge 3	F-value
Dark	12.613***	Flesh Texture	10.080***	Texture Of Skin	0.087
Light	10.777***	Juicy	1.457	Flavour	3.900*
Sweet	0.149	Sour	8.000**	Colour Of Flesh	10.200***
Firmness (Between Fingers)	0.572	Colour	6.307**	Juiciness	5.475*
Juicy	1.145	Flesh Colour	2.100	Colour	1.895
Shiny	8.538***	Size	18.6***	Size	3.327*
Firmness (Chewing)	1.371	Sweet	0.508	Sweetness	8.100**
Sour	7.008**	Texture (In Fingers)	10.080***	Texture of Flesh	1.709
Crunchy	2.502	Astringent	18.600***		
Powdery	0.704	Cherry/Fruity Flavour	5.475		
Size	8.640***				
Colour Of Inside Flesh	0.986				

Judge 4	F-value	Judge 5	F-value	Judge 6	F-value
Colour Of Flesh	5.325**	Intensity Of Skin Colour	7.759**	Flesh Colour	5.406**
Sweetness	1.065	Size Of Stone	5.270**	Juiciness	3.486*
Juicy	0.864	Size	20.550***	Size	8.297***
Firmness	4.342	Sweetness	0.357	Skin Colour	15.060***
Bitter	5.241**	Firmness	4.338*	Sweetness	4.221*
Grainy	0.392	Cherry Taste	13.379***	Acidity	12.818***
Size	9.720***	Intensity Of Flesh Colour	6.535**	Softness	0.378
Crispy	0.923	Acidity	20.325***	Cherry Flavour	2.766
		Texture in mouth	13.964***		
		Amoount Left On Stone	1.655		

Judge 7	F-value	Judge 8	F-value	Judge 9	F-value
Juiciness	6.987**	Colour	0.64	Ease Of Flesh Off Stone	1.71
Internal Flesh Colour	18.400***	Flavour	0.8	Flesh To Stone Ratio	20.55***
Skin Colour	8.100**	Juiciness	2.85	Aftertaste (lingering sweetness)	6.19**
Size	7.622**	Colour Of Inside	2.21	Size	44.85***
Sweetness	8.000**	Crunchiness	2.33	Colour (Eveness)	0.75
Fruity Acid	6.191**	Size	8.72***	Juiciness	7.05**
Firmness	1.995	Cleaness Of Stone	0.38	Cherry Aroma	0.08
Overall Cherry Flavour	5.475**	Shininess Of Skin	2.57	Touch	23.83***
				Flavour	8.1**

Judge 10	F-value	Judge 11	F-value	Judge 12	F-value
Colour of Flesh	1.46	Skin Colour	9.45***	Size Of Cherry	23.31***
Flavour	2.1	Size	9.45***	Colour Of Skin	4.35*
Size	7.52**	Feel	14.40***	Juiciness	0.38
Sweetness	4.1*	Sweetness	2.95	Sweetness	1.67
Juicy	0.69	Juiciness	8.45***	Stone Size	21.23***
Firmness of Flesh	7.14**	Colour Of Flesh	12.75***	Firmness Of Flesh	4.35*
Colour of Skin	5.58**	Bitterness	8.30***	Colour Of Flesh	11.1***
Firmness To Touch	2.94	Even Colour	0.57	Sourness	0.46
Toughness of Skin	2.29				
Flesh Away From Stone	1.89				
Tart	1.54				

3.3.2.2. Diversity of the attributes generated and used by the panel

Each of the 12 judges generated 7-12 attributes for a total of 107 attributes. The list of attributes generated and the frequency with which they were used by the panel is summarised in the Table below. Size, Juicy/Juiciness and Sweet/Sweetness were the most popular attributes with all (12) judges selecting the first with 11 and 10 judges selecting the latter two respectively. Other popular attributes included various attributes related to colour be it flesh, skin or both and various attributes associated with flavour intensity with over half the judges selecting and assessing these types of attribute.

From the GPA performed on the data it appears that there are 3 factors accounting for 93% of the total variation between the products from the whole set of samples. Factors 1, 2 and 3 accounted for 52%, 24% and 17% respectively of the total variation perceived within the product set. The GPA plot of F1 Vs F2 displaying 76% of the total variation showed that some attributes had a similar meaning for the different judges. On observation of the GPA plot F1 Vs F2 from all three evaluation sessions combined axis 1 appears to be dominated by size but flesh colour also has an influence. All but one of the judges assessing size and flesh colour seem to have a similar perception of these two attributes ranking shades of cherry from light to dark and size from small to large whereas Judge 4 uses the scales in reverse. This can be seen on the attributes plot with all attributes associated with flesh colour and size

closely correlated to the positive region of axis 1 and yet the perception of Judge 4 who assessed flesh colour and size can be seen closely correlated to the negative region. It appears that Factor 1 is predominantly defined by size with cherries moving from smaller to larger when moving from the negative to the positive region. Not only is factor 1 defined by size but flesh colour appears to have an underlying influence as well, where cherries of a similar size appear to be separated by their flesh colour. Size is clearly the dominating factor of the two with 12 attributes highly correlated to axis 1, twice as many as flesh colour with just 6 attributes. There are some flavour attributes correlated to this axis which comes as no surprise as it has been shown before that size is directly related to flavour development and ripening. Sweet cherry ripening occurs concomitantly with rapid increase in fruit size and weight during the last few weeks prior to harvest, as much as 25% of final fruit weight is added in that last week of growth before harvest (Looney *et al.*, 1996). It has also been shown that consumer perception of flavour is associated to colour with the assumption that darker cherries will have more flavour than the lighter varieties (Crisosto *et al.*, 2003).

Factor 2 appears to be co-dominated by textural attributes and skin colour, with darker, firmer cherries lying in the positive region and lighter, juicier cherries in the negative region. On observation of the plot skin colour seems to display a more exclusive correlation to axis 2 whereas the textural attributes show a slight clockwise skew spreading toward axis 1.

Factor 3 appears to be defined exclusively by colour, more specifically the colour perceptions of the Judge's whose assessments did not correlate to Factor 2. The darker cherries appear to be those lying in the negative region progressing to a lighter colour moving into the positive region of axis 3. However after observing the raw data i.e. the actual rank scores, Judge 1 has a completely different perception of skin colour to the other judges. The samples Judge 1 ranked as light in skin colour the others generally ranked them as dark and those which Judge 1 ranked as dark the others generally ranked them as light. This can be seen on the plot as Judge 1 did not assess colour as one attribute but as separate attributes dark and light.

Table 3.4: List of attributes generated and used by the panel for the Flash Profile

Modality/Attribute	Number of judges using the same attribute
Appearance	
Dark	1
Light	1
Shiny/Shininess Of Skin	2
Size/Size Of Cherry	12
Colour Of Inside Flesh/Flesh Colour/Colour Of Flesh/Internal flesh Colour/Colour Of Inside	4
Colour	3
Intensity Of Skin Colour	1
Size Of Stone/Stone Size	2
Intensity Of Flesh Colour	1
Amoount Left On Stone/Cleaness Of Stone	1
Skin Colour/Colour Of Skin	5
Colour (Eveness)/Even Colour	2
Flesh To Stone Ratio	1
Ease Of Flesh Off Stone/Flesh Away from Stone/Cleaness Of Stone	3
Texture by fingers	
Firmness (Between Fingers)/Firmness/Firmness To Touch	4
Texture (In Fingers)	1
Texture Of Skin	1
Softness	1
Touch	1
Feel	1
Texture by mouth	
Firmness (Chewing)/Firmness	2
Juicy/Juiciness	11
Crunchy/Crunchiness	2
Powdery	1
Flesh Texture/Texture Of Flesh	2
Astringent	1
Grainy	1
Crispy	1
Texture in mouth	1
Toughness of Skin	1
Firmness of Flesh	2
Aroma	
Cherry Aroma	1
Flavour	
Sweet/Sweetness	10
Sour/Sourness	2
Cherry/Fruity Flavour	2
Flavour	4
Bitter/Bitterness	2
Cherry Taste	1
Acidity	2
Cherry Flavour	1
Fruity Acid	1
Overall Cherry Flavour	1
Aftertaste (lingering sweetness)	1
Tart	1

3.3.2.3. The relative sensory positioning of fresh sweet cherries

The GPA plot F1 Vs F2 of the combined evaluation sessions discriminates the cherry samples by regions as the three British samples originating from Kent, Colney, Regina and Stella are grouped together plus the U.S. Bing and Canadian Lapins are also grouped. Although the Bing and Lapins originate from different countries, geographically their regions are very close, with the Bing originating close to the North East U.S. border and the Lapins from South East Canada, also near the border. The one sample originating from a unique region within the product set, the Spanish Picotta, is isolated from the rest of the samples on the GPA plot showing it is clearly different to the rest. The main difference was its size, Picotta was much smaller than the rest of the cherries in the sample set and this was demonstrated on the plot by its positioning well into the negative region more so than any other sample. The other five cherries were of similar sizing, Lapins was slightly bigger and darker in Flesh colour than Bing which is why its positioning is further to the right in the positive region of axis 1. Regina was also bigger with a darker flesh colour than the other British cherries but its flesh colour was still relatively light in comparison to the whole product set. So its positioning relates well to its description as its relatively light flesh colour to the whole product set situates it in the middle of axis 1 close to the other British cherries but with slightly more positive values displayed than the rest of the British cherries because in relation to them it has a slightly darker flesh colour.

The discrimination and grouping of the cherries on axis 2 was defined by skin colour and juiciness, with Lapins, Bing and Picotta displaying a dark red – black colour and were positioned in the positive region whilst the British varieties were red – dark red and were positioned in the negative region. Inspection of the raw data showed that the British varieties displayed a greater juiciness in texture as their values were ranked highly for attributes associated with juiciness plus they ranked lowly for attributes associated with firmness whereas the Lapins, Bing and Picotta displayed opposing values. From my own observations of the cherries Picotta and Lapins were very dry but Bing had plenty of juice, which could be why that although it is mainly positioned in the positive region there appears to be some spread in to the negative region of axis 2.

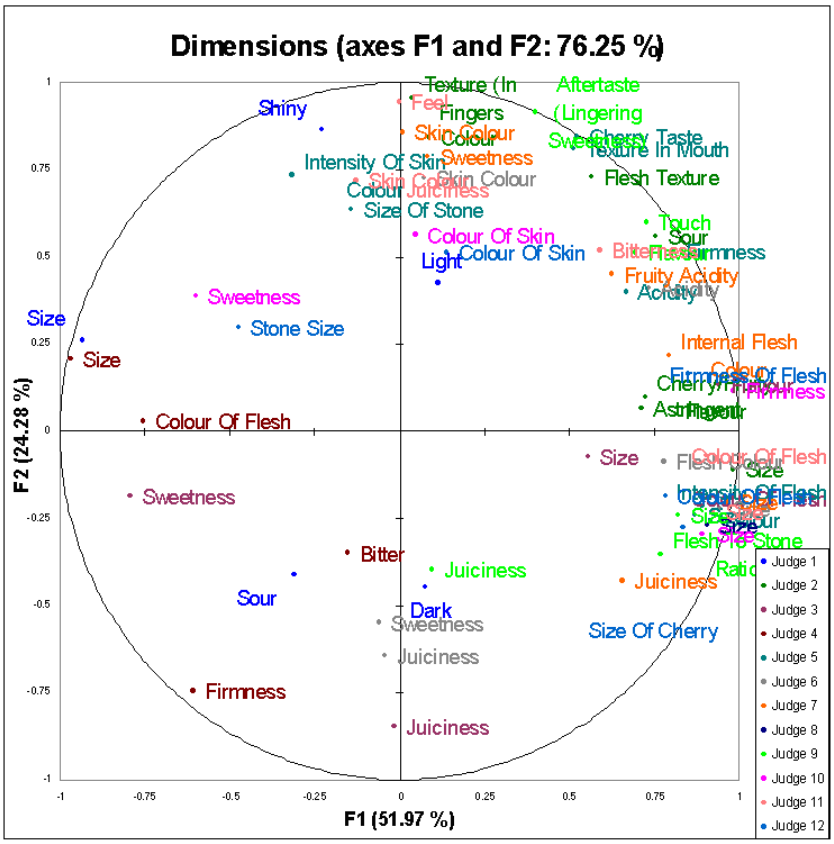
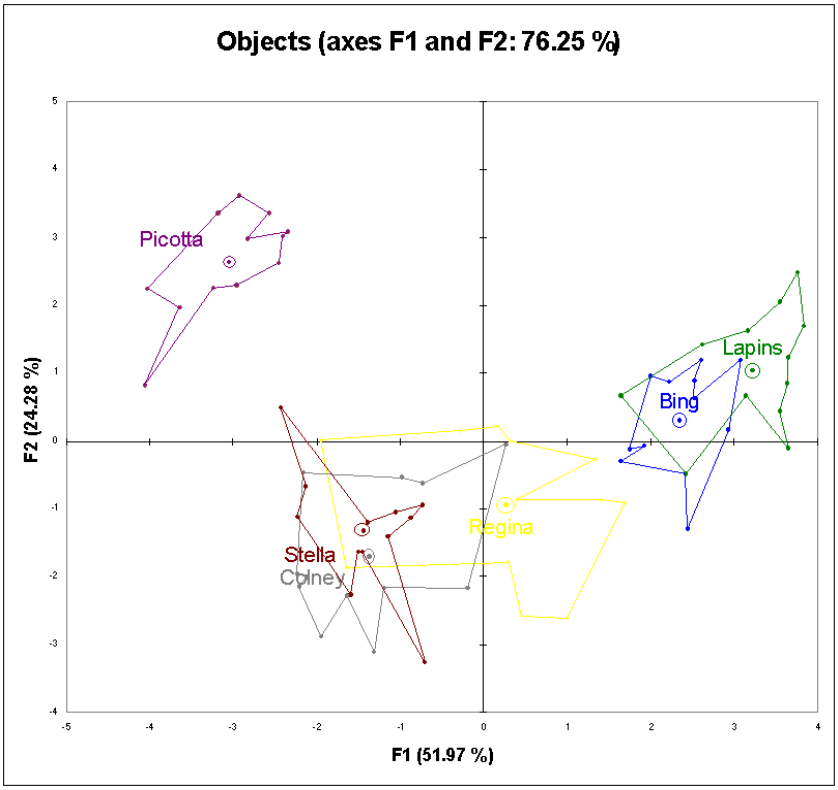


Figure 3.11: Plots of the GPA performed on the sensory data from the evaluation sessions combined. (**A**) Variables plot determined by the first two axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).



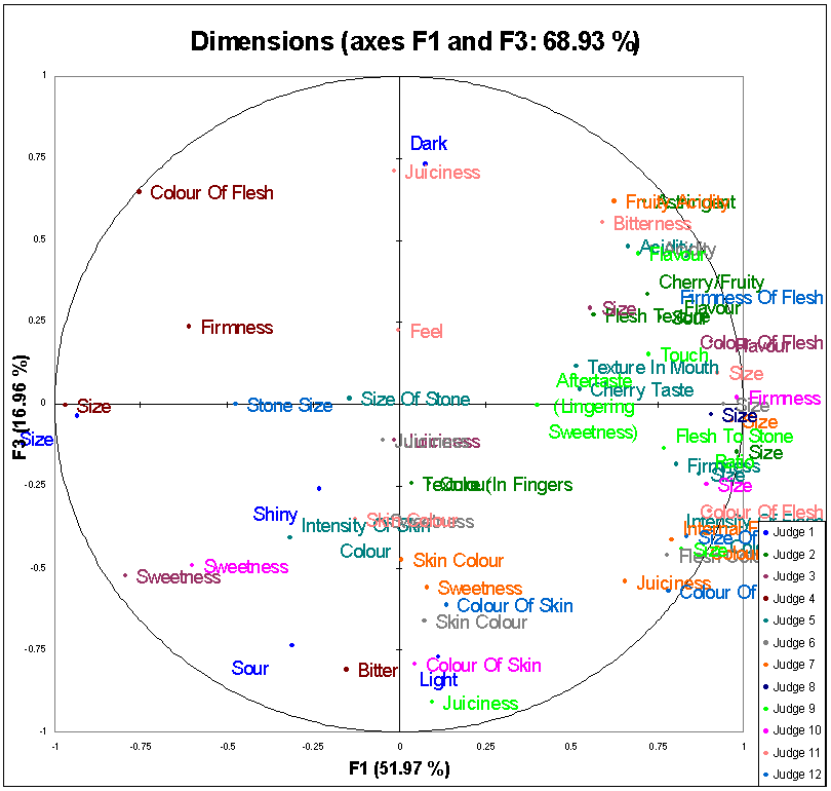
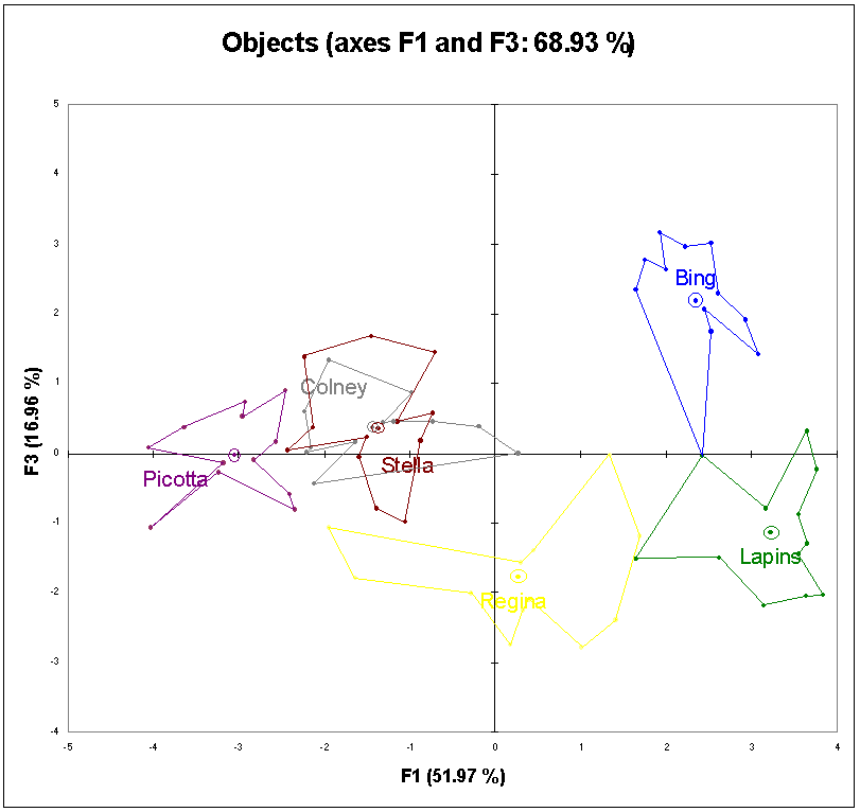


Figure 3.11: Plots of the GPA performed on the sensory data from the evaluation sessions combined. (**A**) Variables plot determined by the first and third axis of the GPA. (**B**) Plot of the average configuration of samples determined by the first two axis of the GPA (individual configurations superimposed).



The GPA plot of F1 Vs F3 provided discrimination of products which were grouped together on the previous plot. Lapins had a darker skin colour than Bing and this can be seen in the separation on axis 3 with Lapins positioning in the darker negative region whilst Bing is located in the positive region. As mentioned above Regina was the darkest of the British varieties regarding it internal flesh colour but this was also true for skin colour. The plot of F1 Vs F3 displays this difference with Regina's positioning entirely in the negative region of axis 3 whereas the other British varieties.

3.4. Consumer Testing and Internal Preference Mapping of 6 Sweet Cherry Varieties

3.4.1. Methods

3.4.1.1. Selection of the sweet cherry samples

Refer to Chapter 3.3.1.1 as the same varieties of cherry taken from the same sources were also used in this consumer study but they were received a week later. It must also be noted that these samples may well have been picked later which could have an impact on their sweetness, size and texture given the fact that the cherries can change rapidly in a single week prior to harvest (Looney *et al.*, 1996). They could well be bigger, sweeter and softer than the equivalent samples analysed the week before in the Flash Profile described in Chapter 3.3.

3.4.1.2. Consumer Panel

A panel of 103 anonymous assessors with no previous sensory experience with sweet cherries were recruited. Consumers were recruited from across the University of Nottingham, Sutton Bonington Campus and its immediate surrounding areas within the boroughs of Rushcliffe (Nottinghamshire) and Charnwood (Leicestershire). All assessors volunteered on the basis that they enjoyed consuming and would be likely to purchase fresh sweet cherries.

3.4.1.3. Consumer Sensory Evaluation

A rank-rating method was used to assess liking of the 6 cherry samples relative to each other. The first session in the sensory booths involved ranking the cherry samples in order of preference from least to most when presented simultaneously to the consumers and the length of this session averaged at approximately 7 minutes, ranging from 5-15 minutes. A 10 minute break was then given to the consumers before moving on to the second session.

The second session in the booths involved transferring the rank data of cherries on to a LAM rating scale (see appendix) in order to define the size of the differences between the rank positions of preference, uncovering which cherries were liked and which were disliked by each consumer. This was achieved by presenting samples monadically, in two sessions of three samples with a 10 minute break in between, in an order determined by each consumer in the first evaluation session. Each consumer's least preferred sample was presented first progressing to their most preferred.

Data was collected manually with consumers recording their rank responses to the first session on a single response sheet. This response sheet was presented to the consumers prior to the rating exercise in the second evaluation session and this was to remind them which order they had ranked the sample in the first evaluation session. Although samples were presented monadically in two sessions of three samples for the second evaluation, the responses or ratings of all six samples were placed on the same single LAM scale in the same rank order defined in the first evaluation session.

3.4.1.4. Protocol For Sample Presentation

For the first (rank exercise) evaluation session cherry samples (3 whole cherries) were presented in identical white polystyrene pots, each labelled with a randomly generated 3 digit code, in a randomised balanced order across the consumer assessors. All 6 samples were presented simultaneously in this first session in the booths and consumers tasted the samples in order first but were allowed to re-taste in any order afterwards. After this session a 10 minute break was given prior to starting the second (rating exercise) evaluation.

For the second evaluation session cherry samples were presented in the same pots described above. Samples were presented monadically in two sessions of three samples with a 10 minute break in between, rather than simultaneously. The presentation order of the samples in this session was defined by each consumers rank preference data in the first session, their least preferred presented first progressing to their most preferred last. Samples were removed from refrigeration (4-6°C) no less than 2 hours before presentation for assessment in the first evaluation so that samples could reach room temperature.

3.4.1.5. Statistical processing of the consumer data

The rating responses were placed on to a percentage scale where 50% represented neither like nor dislike, >50% displayed liking and <50% disliking. Principal Component Analysis (PCA) (Pearson, 1901) was applied to the data from the rating exercise to assess consumer agreement and disagreement in their liking and disliking of fresh sweet cherry varieties. Supplementary data from the Flash Profile in Chapter 3.3 and analytical data in the form of refractive index and pH were also added to the data matrices. This generated an extended internal preference map (McEwan *et al.*, 1998) which illustrated the relative positioning of the products, the consumers, the attributes from the Flash Profile and the two sources of analytical data. An agglomerative hierarchical clustering (AHC) analysis based on Euclidean distance of dissimilarity was applied to the data to draw out groups of consumers who agreed in their liking and disliking from the internal preference map and those who disagreed (i.e. the different groups). The agglomeration method used on the data was unweighted pair-group average and there was no centering, reduction or specific truncation applied either. The PCA and the AHC were performed using XLSTAT add-in software for Microsoft Excel.

3.4.2. Results

3.4.2.1. Extended Internal Preference Map

From the PCA performed on the data it appears there are 3 factors associated with liking and disliking of the cherry products accounting for 77% of the variation in

preference. Factors 1, 2 and 3 accounted for 31%, 26% and 20% respectively of the total variation in preference between the products from the whole set of samples. The PCA plot of F1 Vs F2 displaying 58% of the total variation in perception showed that Factor 1 denoted a preference for flavour intensity with the products towards the positive region displaying a more intense flavour and the consumers also within that region displaying preferences to these products driven by their more intense flavour. The analytical data supports this with refractory index (brix) also lying in the positive region of factor 1 and pH in the negative region. pH is in the negative suggesting a possible sweet-sour axis but this is not the case as higher pH values are what is driving products towards the negative region and so there relative acidity is lower so products in the positive region are sweeter and more acidic generating a more intense flavour.

Factor 2 appears to be show a variation in preference of consumers probably driven by juiciness, as this attribute appears to dominate the positive region of this axis, suggesting the consumers in the positive region are drawn to the products in the same region due to their juicier characteristics and those in the negative region by their drier texture.

Factor 3 appears to show a variation in preference of consumers driven by size, as this attribute appears to dominate the positive region of this axis, suggesting the consumers in the positive region are drawn to the products in the same region due to their larger size. All the cherries were quite similar in size and differences were discrete however Picotta was much smaller than the rest and this is shown on Factor 3 as Picotta is a clear outlier to the rest located very far into the negative region. There were two size attributes plotted in the negative region of axis 3 but on inspection of the raw data the source of this were judges 1 and 4 from the last Flash Profile (Chapter 3.3) using size scales in reverse to the others i.e. large to small instead small to large.

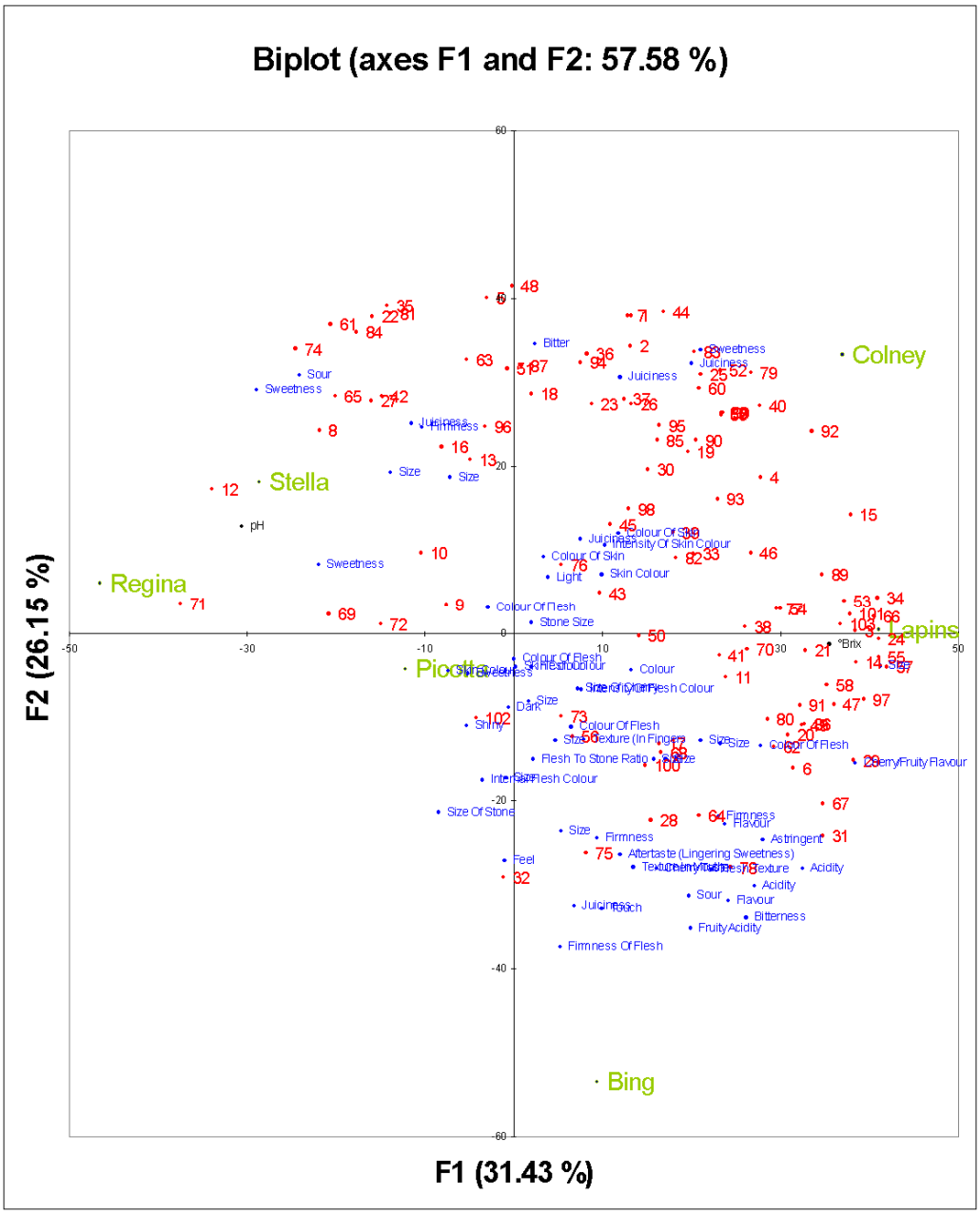


Figure 3.12: Illustrates the two prime factors of variance in consumer preferences

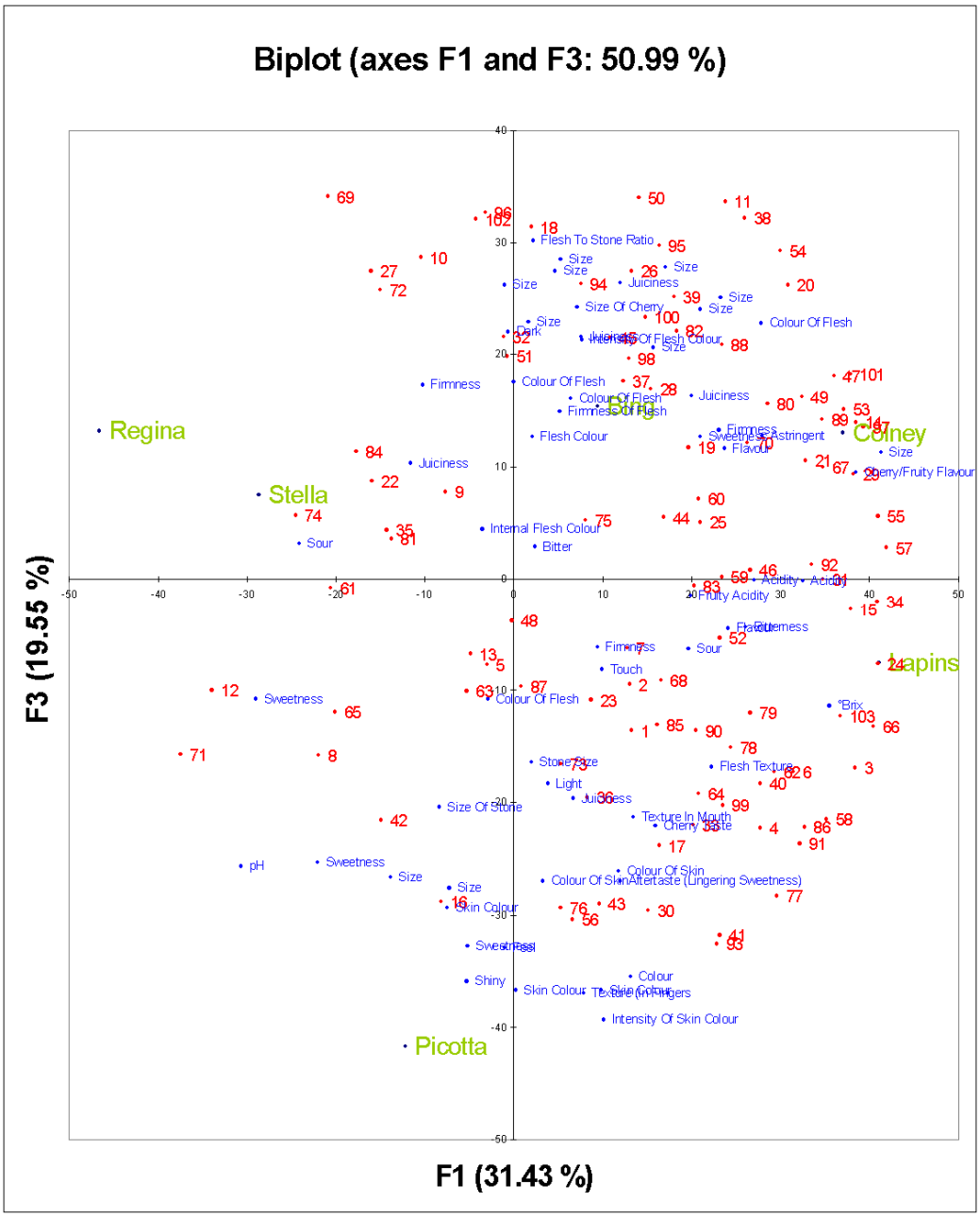


Figure 3.13: Illustrates the first and third factors of variance in consumer preferences

3.4.2.2 Agglomerative Hierarchical Cluster (AHC) Analysis

Figure 3.14 displays the dendrogram which identified 12 classes (or clusters) from the 103 consumers who participated in the study and it illustrates the dissimilarity between those classes. Table 3.5 highlights the total number of consumers in each class and of the 12 classes only 3 appear to be of any marketing value, as the rest consist of either only 3 consumers or less (2.91% of the sample population or less).

Figure 3.14: Displays the truncation which defined 12 Classes based on Euclidean dissimilarity

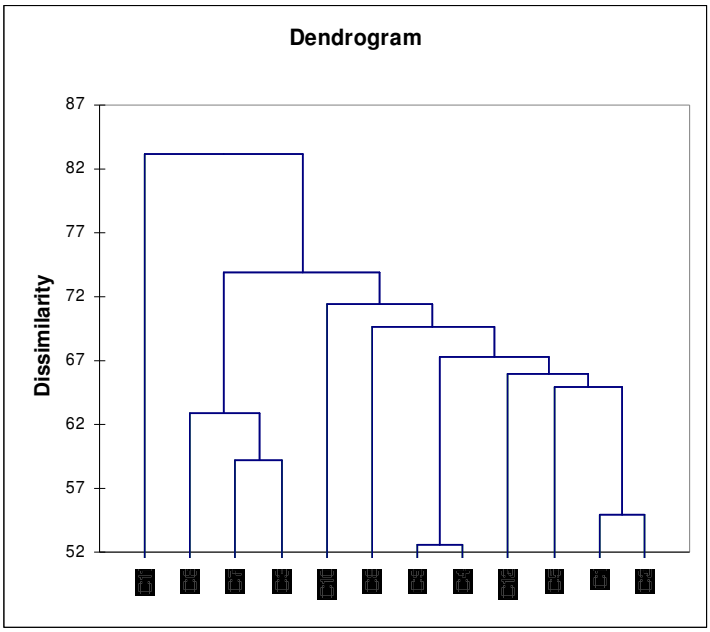


Table 3.5: Illustrates the populations within the 12 classes

Class	1	2	3	4	5	6	7	8	9	10	11	12
Objects	22	56	2	3	3	3	9	1	1	1	1	1

The 3 classes of marketing relevance totalled 87 consumers (84% of the sample population) and were identified as classes 1, 2 and 7 from the original 12 classes. Class 1, 2, and 7 consisted of 22, 56 and 9 consumers (21%, 54% and 9% of the sample population) respectively and the mean average scores of the products allocated by these three classes can be seen in Figure 3.15

The most abundant class or that with the largest number of consumers and therefore the most significant commercially was Class 2 and this class displayed a trend of liking across all the cherry samples; none of the samples were disliked. The two varieties the consumers in this class preferred most appeared to be Lapins and

Colney both of which were liked between ‘moderately’ to ‘very much’ followed by Picotta and Bing ‘moderately’, then Stella and Regina ‘slightly’. The preference to Lapins appeared to be driven by its relatively intense flavour and the preference to Colney by its relatively juicier texture.

The second class of commercial significance was Class 1 and this class also displayed a preference to Lapins and Colney liking, both between ‘moderate’ and ‘very much’ but with slightly lower ratings observed in Class 2. They showed a ‘slightly’ to ‘moderate’ liking of Stella, Regina and Picotta, but the most popular cherry in terms of presence on the global market, Bing, was moderately disliked. The preference towards Lapins and Colney again suggested that preferences in Class 1 were also being driven by Flavour and Juiciness. What is interesting in this class is there also appears to be a driver behind dislike although, Stella, Regina and Picotta were not perceived to have as much flavour (which is supported by relatively lower brix and higher pH) they did have a level of juiciness between Colney and Lapins which was satisfactory and were therefore liked slightly. Bing was perceived to have more flavour than the previous three but its texture was dry and lacked juice and this dry texture appears to be the factor driving the dislike seen in this class.

The third and final class of commercial significance was Class 7 which displayed a preference to the three varieties perceived to be the juiciest Colney, Stella and Regina, all of which were British in origin. Colney was the preferred variety displaying ‘moderate’ liking followed by Regina and Stella with a ‘slight’ to ‘moderate’ liking. The Spanish Picotta was ‘neither liked nor disliked’ and the two North American samples Lapins and Bing were disliked ‘slightly to ‘moderately’ and ‘very much’ respectively. The preference within Class 7, according to the internal preference map, appears to be driven by juiciness but there is the underlying factor of origin, it could well be that this class of consumers are used to eating British cherries and have developed a liking to them and a dislike to others.

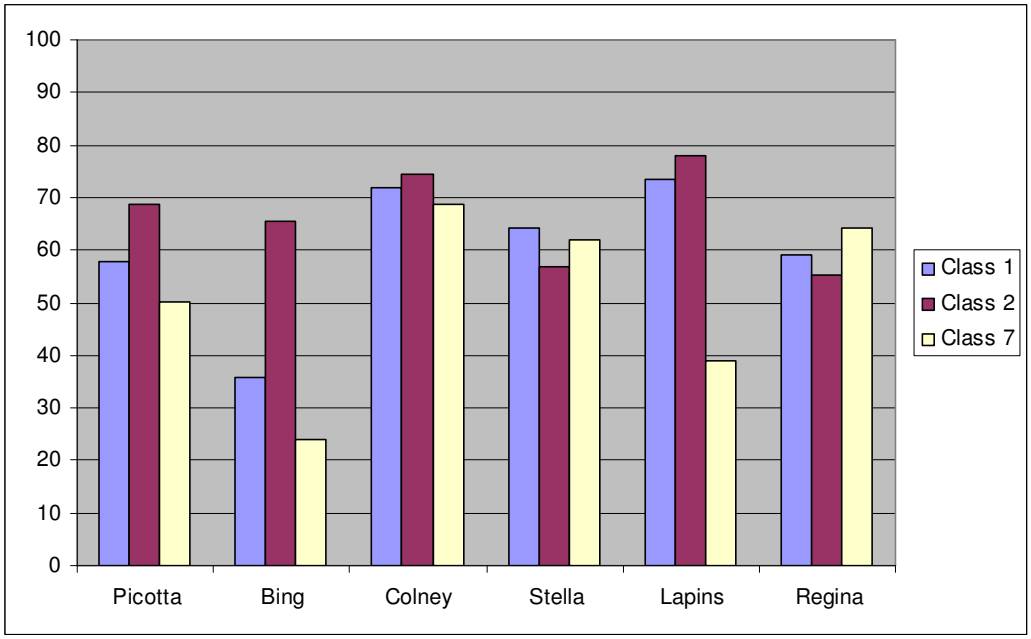


Figure 3.15: Displays the LAM rating scores of the three most highly populated classes

Table 3.6: Displays the LAM rating scores of the three most highly populated classes as it is not easy to pick out exact values on the graph above

Class	Picotta	Bing	Colney	Stella	Lapins	Regina
1	57.949	35.897	71.795	64.103	73.333	58.974
2	68.718	65.641	74.359	56.923	77.949	55.385
7	50.256	24.103	68.718	62.051	38.974	64.103

3.4.3. Discussion

Interpreting the drivers of preference from the supplementary data in the internal preference map is not easy as it is limited in what can be drawn out of it, but, by determining which of the products were most preferred, coupled with the observation of their description from the perceptions in the Flash Profile, a further interpretation and understanding can be achieved.

The liking of Colney was considered to be 'moderate' or greater by all three of the Classes of commercial significance described above (in Chapter 3.4.2.2) which accounts for 84% of the consumers in the sample population and Lapins was liked 'moderately' to 'very much'. The internal preference map suggests this was driven by flavour intensity and juiciness but this interpretation could well be expanded by observing their descriptions from the Flash Profile. The description of Lapins taken from assessors perceptions in the Flash Profile suggest it was not only flavoursome but big and dark, two other characteristics which have been shown to attract consumer

liking (Crisosto *et al.*, 2003). The description of Colney taken from assessors perceptions in the Flash Profile also suggest it was relatively very juicy but that it had lighter skin and flesh and was not so flavoursome relative to the other samples. It has been shown in previous work that there is a preference for darker cherries (Crisosto *et al.*, 2003) so it is unlikely that these characteristics are driving consumers preference to this product. There are limitations to the Flash Profile technique and I believe one such limitation can be demonstrated in that the Flash Profile suggests Colney is not flavoursome relative to the other products yet the internal preference map and analytical data (brix and pH) contradict this. It is possible that interactions between attributes may have taken place when assessing the flavour of Colney in the Flash Profile. It has been shown previously (Kappel *et al.*, 1996) that assessors assume darker cherries to be sweeter and lighter cherries less, this could possibly explain the lack of perceived flavour in the Flash Profile data as the appearance of the samples was not masked when assessing flavours.

4. Project Review

This chapter aims to discuss the relatively new descriptive analysis technique that is Flash Profiling on a range of areas concerning the methodology it uses from its statistical processing and interpretation to its practicalities. It looks to explain advantages, limitations and suitability, where it could prove to be more appropriate in some cases than conventional techniques such as QDA® so comparisons and contrasts to these techniques will be made throughout the review. The chapter will also look at where possible refinements to the techniques and methods applied during this project could be made to improve the data in how it is validated and/or interpreted. There will also be a discussion on the context of these experiments and what directions future work may take from this.

4.1. The Flash Profile Methodology Review

The concept of descriptive analysis is a total sensory description, taking into account all possible perceptions of a product evaluation from visual, auditory, olfactory, taste and kinesthetic sensations (Stone & Sidel, 2004). The most common methodology in sensory evaluation at present appears to be QDA®, but this approach has its drawbacks. It is very time-consuming and costly to set up as it requires long and expensive training of panellists to provide results that are reliable and consistent (Rodrigue *et al.*, 2000). QDA® is a method which provides a lot of useful information to the food (and cosmetic) industry but the cost and time in an industry which is dynamic and ever-changing cause conflict. Industry requires rapid turn-over of results to work effectively in the market whilst maintaining and increasing profit margins whereas QDA® is a slow process that needs long-term investment. Large corporate companies may be able justify this investment of money and time but small/medium companies must be convinced of the necessity to use sensory analysis, it is not always viable for them financially.

The time and cost of QDA® is the training of the panel to a consensual understanding of the attributes/terms being assessed and consistent use of the corresponding scales can take from 10 hours or more, spread across a number of weeks and sometimes months; it really depends on the nature of the product, the

attributes being assessed and the objective of the study. One such QDA® study applied to chocolate took one year of two sessions per week to train a panel to a level of expertise (Sune *et al.*, 2002), plus, once training is completed, more time is then needed to actually run the test to obtain the final results. Flash Profiling by-passes this training stage as consensual meanings are not required; instead each panelist generates their own descriptive terms with which they wish to use to evaluate the products similar to that of the Free Choice Profiling (FCP) method (Williams & Langron, 1997). A sensory map is obtained for each panelist via PCA, the consensual stage is then achieved statistically through GPA (Gower, 1975) which basically rotates and scales each assessor's PCA configuration in to one consensus sensory map. Flash Profiling also differs to FCP in that the products are presented simultaneously and are ranked in relation to the whole product set allowing better discrimination of the products as direct comparisons can be made. FCP like QDA® involved rating samples and also requires training sessions but unlike QDA® it is individual training rather than as a group. Flash Profiling provides a practical alternative to the conventional approaches and its practicalities will expanded in the following Chapter but like most scientific methods it is not perfect.

4.1.1. Statistical Limitations

There are limitations to using rank data as it assumes that there is an equal magnitude of difference between rank positions, yet the scales used in this experiment were blank and some products were clustered at one end of the scale and others clustered at the opposite. An example of this was observed in the raw Flash Profile data from Chapter 3.1 associated with colour differences, the two Ferrovia varieties were clustered at the 'Light/Bright red' end of the scale and the four Bing varieties at the 'Dark Red/Black' end of the scale. The result was that between rank positions within a variety there was a small difference perceived i.e between 1-2 for Ferrovia and 3-4-5-6 for Bing but there was a vast difference between the two varieties Ferrovia and Bing i.e. rank positions 3-4. This difference could not be accounted for in the statistical processing and this led to a reduction in the perceived difference displayed on the GPA plot. It would be interesting to see what would happen to the data if it were rank-rated in the sense that the panellists be asked to rank them in order on the scales but the distances be measured and parametric values put in to the GPA

rather than non-parametric, but training would then be required in use of the scales. This would also suit the fact that significant differences in the raw data (which was non-parametric) were determined using ANOVA because Friedmann's could not handle repetitions. Applying ANOVA to this non-parametric data could lead to a type II error, possibly from the reduction effect described above where there was a clear difference between Ferrovia and Bing which could have been truly uncovered had parametric scores been recorded. There are other statistical limitations associated with the GPA analysis as variance in the descriptions and the samples themselves is lost through the formation of the consensus space. Variance is lost from the Procrustes procedure of scaling and rotating, followed by averaging of each panellist's space and also from the generation of the final PCA which creates the consensus plot (Dijksterhuis, 1997).

4.1.2. Practicalities

The duration of the test from beginning to end took 5 days with panellists attending 4 sessions of approximately 2¼ hours, this is a lot less time than what would have been required for the QDA® approach, training alone would have exceeded this. Processing the data to create the GPA plots required another 5 days, so two weeks from undertaking the test to extracting meaningful results can allow swift and decisive actions to be taken by companies in industry who may use this method. The total time spent by the experimenter to prepare and run the sessions, input data into the computer and run the statistical analysis took 105 hours and the quantity of cherries required to run the test was 7kg of each cherry sample. The time of 105 hours could have been reduced significantly had the panellists all attended together, but this is an advantage for them in that they do not all need to be present when sessions are run which gives them flexibility in attendance. The time consumed preparing and running tests came to a total of 65 hours but had they conveniently attended at the same time it could have been reduced to 20 hours. For industry the Flash Profile has clear benefits as it is likely that less time is consumed to run the test therefore the output of results is quicker, the experimenter running the test works less hours in total and this is true of the panellists so both would therefore be of cheaper cost (if external and being paid) and the amount of product consumed is likely to be less. Dairou &

Siefferman (2002) demonstrated these points when they compared the Flash Profile to the conventional QDA® approach using a variety of jam products and Delarue & Sieffermann (2003) demonstrated this with a more similar group of samples using fruit dairy products.

A practical advantage specific to this project was the relatively short duration of the test from start to finish. Cherries are highly perishable and subject to changes in their sensory properties over short periods of time, the shelf-life was 6 days so the test had to be completed within the working week. Cherry seasons are short, only three weeks per variety, but the fruiting of cultivars vary and overlap to extend the seasons within a region. Applying QDA® would be difficult, near impossible, to cherries as availability of the product is restricted; time consumed during training may be similar to other products but this time would be much more spread across at least a year or two based on this limited availability across the year. Availability of cherries could also be seen as a disadvantage to the Flash Profile technique as all products must be available so they can be presented simultaneously to the assessor. As mentioned above the seasons of cherry varieties overlap but it is sometimes difficult to source an array of varieties global market is usually dominated by one or two varieties at any given time. This proved to be the case in June, a poor crop in France meant that only the Italian Ferrovia and the Californian Bing were available for the experiment described in Chapter 3.1, but sub-samples were created from the two varieties based on supplier/farm origin.

Some of the practical advantages are summarised below (IFST PFSG discussion forum, 2008):

Quick to perform

- Assessors do not need to familiarise themselves with the samples
- No training phase as a precise and consensual attribute list (terms and definitions) is not needed
- Less time-intensive for the experimenter (less sample preparation, fewer sessions)

Simpler organization:

- Each session is conducted on an individual basis, there is no need for group sessions

- Samples are prepared prior to evaluation session and presented all simultaneously
- The presence of an experimenter is not required

Free choices of attributes:

- A common vocabulary is not imposed to the assessors
- Terms are produced on an individual basis, enriching the description by its specificity
- Only discriminative terms are generated
- Illustrate the importance of each sensory modality depending on each individual.

4.1.3. Suitability

As mentioned above the Flash Profile is much more suitable than conventional techniques when product availability is restricted or shelf-life is limited i.e. seasonal and perishable products such as fresh produce, due to the relatively short duration required to complete the assessment of products. Assessors with sensory experience are a pre-requisite to the Flash Profile technique but if the assessors are already trained to the products that are to be analysed, then standard profiling would seem more appropriate as more validated, detailed information could be extracted. Although, that said, it could also be used effectively as a pre-screening tool to obtain a quick profile or overview of the market which would be useful for companies undertaking a category review which required quick results. As a pre-screening tool, it could also be used to distinguish whether products in a set differ greatly or discretely and determine whether companies undertake descriptive tests or discrimination tests to obtain detailed explanations of perception differences.

It is not an appropriate technique where the products being assessed require careful temperature controls as this will be difficult to achieve when presenting several samples simultaneously. It is also not appropriate if a lot of samples require assessment but this ultimately depends on the product, 12 cherry samples was too much and it confused the panel and generated meaningless data, 6-8 was considered optimum but, as in most sensory tests, these numbers depend on the nature of the product. There is also a minimum number required to give sufficient sensible outputs

e.g. 4 products, but the advantage of the Flash Profile technique is that it permits direct comparisons so it would be more appropriate to work towards the maximum number of products to obtain optimum functionality of the method.

4.2. Future Work

Taking this work forward in terms of the methodology that was applied would involve modifications to the Flash Profile technique. The prime modification would be to employ the rank-rating referred to in Chapter 4.1.1 where-by parametric data is obtained and this would require training the panellists on use of scales so that they are consistent but this would restrict the technique in one of its main advantages, its rapid turnaround of data. The training would still be less time-consuming and quicker than that observed in QDA® as consensus training would not be required.

It was highlighted previously that there was a possibility of issues concerning multimodal interactions between attributes where it was suggested that assessors were 'tasting with their eyes' so to speak. Kappel *et al.*, (1996) also demonstrated this, where assessors assume darker skin colour equates to more sweetness and lighter skin colour less sweetness. This could be overcome by blind-folding the panellists or with the use of a light filter to present the samples under red light.

4.3. Conclusion relating to the original hypotheses

The Flash Profile is a viable alternative method particularly for small/medium companies in industry which can be used to provide a comprehensive sensory profile suitable for descriptive analysis at a relatively cheaper cost than conventional methods. It has potential applications as a pre-screening tool, in providing a quick market overview and as an alternative to QDA® where product is limited by time and availability.

The combined interpretations of Flash Profile and extended internal preference map data were able to illustrate and explain consumer preference in sufficient depth to reveal key drivers. Preference was primarily driven by flavour followed by juiciness where there is a clear preference towards cherries with intense flavours combined

with a juicy texture. Acceptability or in this case unacceptability appeared to be driven by a lack of juice or dry texture rather than a lack of flavour.

5. Bibliography

Bibliography

Anon. The Euro+Med Plantbase Project - Taxon Summary Page. Berlin-Dahlem: Botanic Garden and Botanical Museum, 2006. Available at: <http://ww2.bgbm.org/_EuroPlusMed/PTaxonDetail.asp?NameId=31189&PTRefFk=500000> Accessed 24/10/07.

Anon. Pp.54 Chapter Annex B: Economic Analysis and Evidence in *Sustainable Food and Farming – Working Together* Document: PB 6950 UK: DEFRA, 29/03/2004. Available at: <http://www.defra.gov.uk/farm/policy/sustain/pdf/workingtogether-annexb.pdf> Accessed 16/10/07.

Anon. Stone fruit situation and outlook in selected countries. US: United States Department of Agriculture - Foreign Agricultural Service, 2005. Available at < http://www.fas.usda.gov/htp/Hort_Circular/2005/08-05/_08-03-05_%20Stone%20Fruit%20Situation%20and%20Outlook.pdf> Accessed 20/10/07.

AGENCY, F. S. (2002) McCance and Widdowson's. The composition of foods. 6th summary ed. Cambridge, United Kingdom: Royal Society of Chemistry.

BARGIONI, G. (1995) Sweet cherry scions: characteristics of the principal commercial cultivars, breeding objectives and methods. *Cherries: crop physiology, production and uses. CAB Intern, Wellingford***,** 73-112.

BARRELT, D. M. & GONZALEZ, C. (1994) Activity of Softening Enzymes during Cherry Maturation. *Journal of Food Science,* 59**,** 574-577.

BERNALTE, M. J., HERNANDEZ, M. T., VIDAL-ARAGON, M. C. & SABIO, E. (1999) Physical, chemical, flavor and sensory characteristics of two sweet cherry varieties grown in 'Valle del Jerte' (Spain). *Journal of Food Quality,* 22**,** 403-416.

BRADY, C. J., MCGLASSON, B. & SPEIRS, J. (1987) Biochemistry of Fruit Ripening. *Plant Biol.,* 4**,** 279-288.

CIVILLE, G. V. & LAWLESS, H. T. (1986) The importance of language in describing perceptions. *Journal of Sensory Studies,* 1**,** 203-215.

CIVILLE, G. V. & LISKA, I. H. (1975) Modifications and applications to foods of the general foods sensory texture profile. *Journal of Texture Studies,* 6**,** 19-31.

CRISOSTO, C. H., CRISOSTO, G. M. & METHENEY, P. (2003) Consumer acceptance of 'Brooks' and 'Bing'cherries is mainly dependent on fruit SSC and visual skin color. *Postharvest Biol. Technol,* 28**,** 159-167.

CRISOSTO, C. H., CRISOSTO, G. M. & RITENOUR, M. A. (2002) Testing the reliability of skin color as an indicator of quality for early season 'Brooks'(Prunus a6ium L.) cherry. *Postharvest Biology and Technology,* 24**,** 147-154.

CRISOSTO, C. H., GARNER, D., DOYLE, J. & DAY, K. R. (1993) Relationship between Fruit Respiration, Bruising Susceptibility, and Temperature in Sweet Cherries. *Hortscience,* 28**,** 133.

DAIROU, V. & SIEFFERMANN, J. M. (2002) A Comparison of 14 Jams Characterized by Conventional Profile and a Quick Original Method, the Flash Profile. *Journal of Food Science,* 67**,** 826-834.

DELARUE, J. & SIEFFERMANN, J. M. (2004) Sensory mapping using Flash profile. Comparison with a conventional descriptive method for the evaluation of the flavour of fruit dairy products. *Food Quality and Preference,* 15**,** 383-392.

DEVER, M. C., MACDONALD, R. A., CLIFF, M. A. & LANE, W. D. (1996) Sensory evaluation of sweet cherry cultivars. *Hortscience,* 31**,** 150-153.

DIJKSTERHUIS, G. B. (1997) *Multivariate Data Analysis in Sensory and Consumer Science*, Wiley-Blackwell.

ESTI, M., CINQUANTA, L., SINESIO, F., MONETA, E. & DI MATTEO, M. (2002) Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage. *Food Chemistry,* 76**,** 399-405.

FENAROLI, E. (1979) Handbook of Flavour Ingredients, Vol. 1. Cleveland, Ohio: CRS Press.

GIRARD, B. & KOPP, T. G. (1998) Physicochemical Characteristics of Selected Sweet Cherry Cultivars. *Journal of Agricultural and Food Chemistry,* 46**,** 471-476.

GOWER, J. C. (1975) Generalized procrustes analysis. *Psychometrika,* 40**,** 33-51.

GREENHOFF, K. & MACFIE, H. J. H. (1994) Preference mapping in practice. *Measurement of Food Preferences***,** 137-166.

GUCCI, R., PETRACEK, P. D. & FLORE, J. A. (1991) The effect of fruit harvest on photosynthetic rate, starch content, and chloroplast ultrastructure in leaves of Prunus avium L. *Advances in Horticultural Science,* 5**,** 19-22.

GUYER, D. E., SINHA, N. K., CHANG, T. S. & CASH, J. N. (1993) Physicochemical and sensory characteristics of selected Michigan sweet cherry (Prunus avium L.) cultivars. *Journal of Food Quality,* 16**,** 355-370.

HARTMANN, C. (1988) Ehtylene and ripening of a non-climacteric fruit: the cherry. ISHS *Acta Horticulturae,* 258: International Symposium on Postharvest Handling of Fruit and Vegetables

HOUGH, G., WAKELING, I., MUCCI, A., CHAMBERS, E., GALLARDO, I. M. & ALVES, L. R. (2006) Number of consumers necessary for sensory acceptability tests. *Food Quality and Preference,* 17**,** 522-526.

IKEDA, K. (2002) New seasonings. J Tokyo Chem Soc 30: 820-836, 1909, in Japanese.[Translated English version (by Ogiwara Y and Ninomiya Y) in. *Chem Senses,* 27**,** 847-849.

ISO 8589:1988 'Sensory analysis - general guidance for the design of test rooms'

ISO 4120:2004 'Sensory analysis - Methodology - Triangle test'

ISO 10399:2004 'Sensory analysis - Methodology - Duo-trio test'

ISO 5495:2005 'Sensory analysis - Methodology - Paired comparison test'

KAPPEL, F., FISHER-FLEMING, B. & HOGUE, E. (1996) Fruit Characteristics and Sensory Attributes of an Ideal Sweet Cherry. *Hortscience,* 31**,** 443-446.

KEITH, E. S. & POWERS, J. J. (1968) Determination of flavor threshold levels and sub-threshold, additive, and concentration effects. *Journal of Food Science,* 33(2), 213-218

LEE III, W. E. & PANGBORN, R. M. (1986) Time-intensity: the temporal aspects of sensory perception. *Food Technoly,* 40**,** 71-82.

LONGSTROTH, M. & PERRY, R. L. (1996) Selecting the orchard site, orchard planning and establishment. *Cherries: Crop physiology, production and uses. CAB International, Cambridge, UK***,** 203-221.

LOONEY, N. E., WEBSTER, A. D. & KUPFERMAN, E. M. (1996) Harvest and handling sweet cherries for the fresh market. *Cherries: Crop Physiology, Production and Uses. CAB International, Cambridge. Edited by Webster, AD & Looney, NE***,** 411–469.

MATTHEIS, J. P., BUCHANAN, D. A. & FELLMAN, J. K. (1992a) Identification of headspace volatile compounds from 'Bing'sweet cherry fruit. *Phytochemistry,* 31**,** 775-777.

MATTHEIS, J. P., BUCHANAN, D. A. & FELLMAN, J. K. (1992b) Volatile compounds emitted by sweet cherries (Prunus avium Cv. Bing) during fruit development and ripening. *Journal of Agricultural and Food Chemistry,* 40**,** 471-474.

MATTHEIS, J. P., BUCHANAN, D. A. & FELLMAN, J. K. (1997) Volatile Constituents of Bing Sweet Cherry Fruit following Controlled Atmosphere Storage. *Journal of Agricultural and Food Chemistry,* 45**,** 212-216.

MCEWAN, J. A., EARTHY, P. J. & DUCHER, C. (1998) *Preference Mapping: A Review*, Campden & Chorleywood Food Research Association.

MEHERIUK, M., GIRARD, B., MOYLS, L., BEVERIDGE, H. J. T., MCKENZIE, D. L., HARRISON, J., WEINTRAUB, S. & HOCKING, R. (1995) Modified atmosphere packaging of 'Lapins' sweet cherry. *Food Research International,* 28**,** 239-244.

MEILGAARD, M., CIVILLE, G. V. & CARR, B. T. (2006) *Sensory Evaluation Techniques*, CRC Press.

NAHRSTEDT, A. (1972) Cyanogenesis of. *Prunus avium Phytochemistry,* 11**,** 3121-3126.

NOBLE, A. C. (1996) Taste-aroma interactions. *Trends in Food Science & Technology,* 7**,** 439-444.

PAILLARD, N. M. (1990) The Flavour of Apples, Pears and Quinces. *The Favours of Fruits. New York: Elsevier, Inc***,** 1-42.

PAILLARD, N. M. M. & ROURI, O. (1984) Production des aldehydes en CQ, hexanal et 2-hexenal par des tissues de pommes broyes. *Lebensm. Wiss. Technol,* 17**,** 345-350.

PETER, D. Grower Manual 3: Commercial Cherry Production, paperback.

PFEIFFER, J.C., HOLLOWOOD, T. A., HORT, J. & TAYLOR, A. J. (2005) Temporal synchrony and integration of sub-threshold taste and smell signals. *Chemical Senses,* 30, 539-545.

RASON, J., LÉGER, L., DUFOUR, E. & LEBECQUE, A. (2006) Relations between the know-how of small-scale facilities and the sensory diversity of traditional dry sausages from the Massif Central in France. *European Food Research and Technology,* 222**,** 580-589.

RODRIGUE, N., GUILLET, M., FORTIN, J. & MARTIN, J. F. (2000) Comparing information obtained from ranking and descriptive tests of four sweet corn products. *Food Quality and Preference,* 11**,** 47-54.

SCHMID, W. & GROSCH, W. (1986a) Identification of Highly Aromatic Volatile Flavor Compounds from Cherries (Prunus-Cerasus L). *Zeitschrift für Lebensmittel-Untersuchung und-Forschung,* 182**,** 407–412.

SCHMID, W. & GROSCH, W. (1986b) Quantitative Analyse flüchtiger Aromastoffe mit hohen Aromawerten in Sauerkirschen (Prunus cerasus L.), Süßkirschen

(Prunus avium L.) und Kirschkonfitüren. *European Food Research and Technology,* 183**,** 39-44.

SEKSE, L. (1995) Fruit cracking in sweet cherries (Prunus avium L.). Some physiological aspects—a mini review. *Scientia Horticulturae,* 63**,** 135-141.

SPAYD, S. E., PROEBSTING, E. L. & HAYRYNEN, L. D. (1986) Influence of crop load and maturity on quality ans susceptibility to bruising of bing sweet cherries. *Journal of the American Society for Horticultural Science,* 111**,** 678-682.

STONE, H., SIDEL, J., OLIVER, S., WOOLSEY, A. & SINGLETON, R. C. (1997) Sensory evaluation by quantitative descriptive analysis. *Descriptive Sensory Analysis in Practice*.

STONE, H. & SIDEL, J. L. (1998) Quantitative descriptive analysis: developments, applications, and the future. *Food Technology,* 52**,** 48-52.

STONE, H. & SIDEL, J. L. (2004) *Sensory Evaluation Practices*, Academic Press.

SUNE, F., LACROIX, P. & HUON DE KERMADEC, F. (2002) A comparison of sensory attribute use by children and experts to evaluate chocolate. *Food Quality and Preference,* 13**,** 545-553.

ULRICH, R. & HULME, A. C. (1970) The biochemistry of fruits and their products. Academic Press.

APPENDIX I – Flavour Analysis

Volatiles - Raw Data

		Mass of extract (µg/kg) fresh cherry tissue		
Grower/Packer	Variety	Benzaldehyde	e-2-Hexenal	Hexanal
Morada	Bing	37.3	603.0	428.5
Morada	Bing	34.3	754.3	518.1
Morada	Bing	32.2	587.1	360.8
Morada	Bing	12.9	518.1	330.5
Sweet Treat	Bing	58.6	384.5	339.9
Sweet Treat	Bing	80.3	393.2	340.6
Sweet Treat	Bing	75.7	398.0	344.0
Sweet Treat	Bing	59.6	812.2	567.9
Lodi Gold	Bing	109.9	1132.5	493.5
Lodi Gold	Bing	128.0	1701.4	637.3
Lodi Gold	Bing	92.0	982.7	390.1
Lodi Gold	Bing	98.4	1093.9	330.9
Delta Fresh	Bing	55.0	457.8	312.7
Delta Fresh	Bing	59.8	492.1	406.2
Delta Fresh	Bing	72.2	1279.6	907.6
Puglia	Ferrovia	18.7	333.9	209.1
Puglia	Ferrovia	17.4	518.6	452.6
Puglia	Ferrovia	17.5	512.4	349.2
Puglia	Ferrovia	13.2	400.4	324.0
Simone	Ferrovia	45.5	578.4	314.6
Simone	Ferrovia	68.4	645.4	511.5
Simone	Ferrovia	48.0	679.8	748.1
Simone	Ferrovia	30.2	270.0	0.0

	Mean average & standard deviation of extracts from fresh cherry tissue (µg/kg)					
	Benzaldehyde		*E*-2-Hexenal		Hexanal	
Grower / Packer	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Morada	29.2	11.1	615.6	99.5	409.4	83.2
Sweet Treat	68.6	11.1	497.0	210.2	398.1	113.2
Lodi Gold	107.1	15.8	1227.6	322.2	463.0	134.3
Delta Fresh	62.3	8.9	743.2	464.9	542.1	319.9
Puglia	16.7	2.4	441.4	89.9	333.7	100.0
Simone	48.0	15.7	543.4	187.1	524.7	217.0

Benzaldehyde

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	20485.727	4097.145	29.091	< 0.0001
Error	17	2394.267	140.839		
Corrected Total	22	22879.994			

Computed against model Y=Mean(Y)

Category	LS means	Groups			
Lodi Gold	107.091	A			
Sweet Treat	68.576		B		
Delta Fresh	62.301		B		
Simone	48.016		B	C	
Morada	29.169			C	D
Puglia	16.690				D

E-2-hexenal

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	1663869.147	332773.829	5.465	0.004
Error	17	1035128.949	60889.938		
Corrected Total	22	2698998.095			

Computed against model Y=Mean(Y)

Category	LS means	Groups	
Lodi Gold	1227.596	A	
Delta Fresh	743.176	A	B
Morada	615.648		B
Simone	543.419		B
Sweet Treat	496.980		B
Puglia	441.350		B

Hexanal

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	110699.430	22139.886	0.801	0.565
Error	16	442207.570	27637.973		
Corrected Total	21	552907.000			

Computed against model Y=Mean(Y)

Category	LS means	Groups
Delta Fresh	542.132	A
Simone	524.736	A
Lodi Gold	462.979	A
Morada	409.441	A
Sweet Treat	398.091	A
Puglia	333.733	A

Non-volatiles – Raw Data

Grower/Packer	Variety	BRIX	pH of dilution	TA/ml of NaOH	TA %
Morada	Bing	20.1	3.83	24.1	1.6147
Morada	Bing	22.9	3.84	27.1	1.8157
Morada	Bing	21.8	3.75	24.5	1.6415
Morada	Bing	21.5	3.8	22.3	1.4941
Sweet Treat	Bing	15.4	3.95	11.2	0.7504
Sweet Treat	Bing	16.6	3.86	14.5	0.9715
Sweet Treat	Bing	18.5	3.91	14	0.938
Sweet Treat	Bing	15.6	3.9	12.4	0.8308
Lodi Gold	Bing	15	3.68	10.8	0.7236
Lodi Gold	Bing	16.7	3.84	9.3	0.6231
Lodi Gold	Bing	17.8	3.86	9.9	0.6633
Lodi Gold	Bing	18.2	3.94	10.1	0.6767
Delta Fresh	Bing	20	3.95	24.8	1.6616
Delta Fresh	Bing	22	3.73	21.3	1.4271
Delta Fresh	Bing	23.5	3.72	19.8	1.3266
Delta Fresh	Bing	20.6	3.8	17.3	1.1591
Puglia	Ferrovia	16.7	4.02		
Puglia	Ferrovia	15.8	3.96	18.1	1.2127
Puglia	Ferrovia	16.8	4.06	18.6	1.2462
Puglia	Ferrovia	17.2	4.03	15.8	1.0586
Simone	Ferrovia	15.5	3.98	16.7	1.1189
Simone	Ferrovia	13.8	4.12	13	0.871
Simone	Ferrovia	13.7	4.06	12.3	0.8241
Simone	Ferrovia	12.7	4.06	13	0.871

		TA %		pH		BRIX	
Grower/Packer	Variety	MEAN	St Dev	MEAN	St Dev	MEAN	St Dev
Morada	Bing	1.64	0.13	3.81	0.04	21.58	1.15
Sweet Treat	Bing	0.87	0.10	3.91	0.04	16.53	1.42
Lodi Gold	Bing	0.67	0.04	3.83	0.11	16.93	1.43
Delta Fresh	Bing	1.39	0.21	3.80	0.11	21.53	1.56
Puglia	Ferrovia	1.17	0.10	4.02	0.04	16.63	1.56
Simone	Ferrovia	0.92	0.13	4.06	0.06	13.93	1.16

Refractive Index - BRIX

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	187.595	37.519	23.642	< 0.0001
Error	18	28.565	1.587		
Corrected Total	23	216.160			

Computed against model Y=Mean(Y)

Category	LS means	Groups		
Morada Delta	21.575	A		
Fresh	21.525	A		
Lodi Gold	16.925		B	
Puglia	16.625		B	C
Sweet Treat	16.525		B	C
Simone	13.925			C

pH

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	0.247	0.049	9.503	0.000
Error	18	0.094	0.005		
Corrected Total	23	0.341			

Computed against model Y=Mean(Y)

Category	LS means	Groups	
Simone	4.055	A	
Puglia	4.018	A	
Sweet Treat	3.905	A	B
Lodi Gold	3.830		B
Morada Delta	3.805		B
Fresh	3.800		B

Titrable Acidity (TA)

Analysis of variance:

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	5	2.600	0.520	29.995	< 0.0001
Error	17	0.295	0.017		
Corrected Total	22	2.894			

Computed against model Y=Mean(Y)

Category	LS means	Groups			
Morada	1.642	A			
Delta Fresh	1.394	A	B		
Puglia	1.173		B	C	
Simone	0.921			C	D
Sweet Treat	0.873			C	D
Lodi Gold	0.672				D

APPENDIX II – Sensory Analysis

Session: Describing Differences **Date:**

Name:

Judge No.: **Age:**

Gender:

Instructions

You have been presented with 'X' samples of whole cherries. Take one bite from each individual cherry presented in each sample in front of you, starting with the sample to your left and finishing with the sample to your right working your way backwards. Please cleanse your palate in between samples with the water and cracker provided. Describe the differences you perceive between the cherries by listing all the attributes / characteristics you can think of in the box provided below.

Attribute: ……

From…….. To……

Method used: ……...

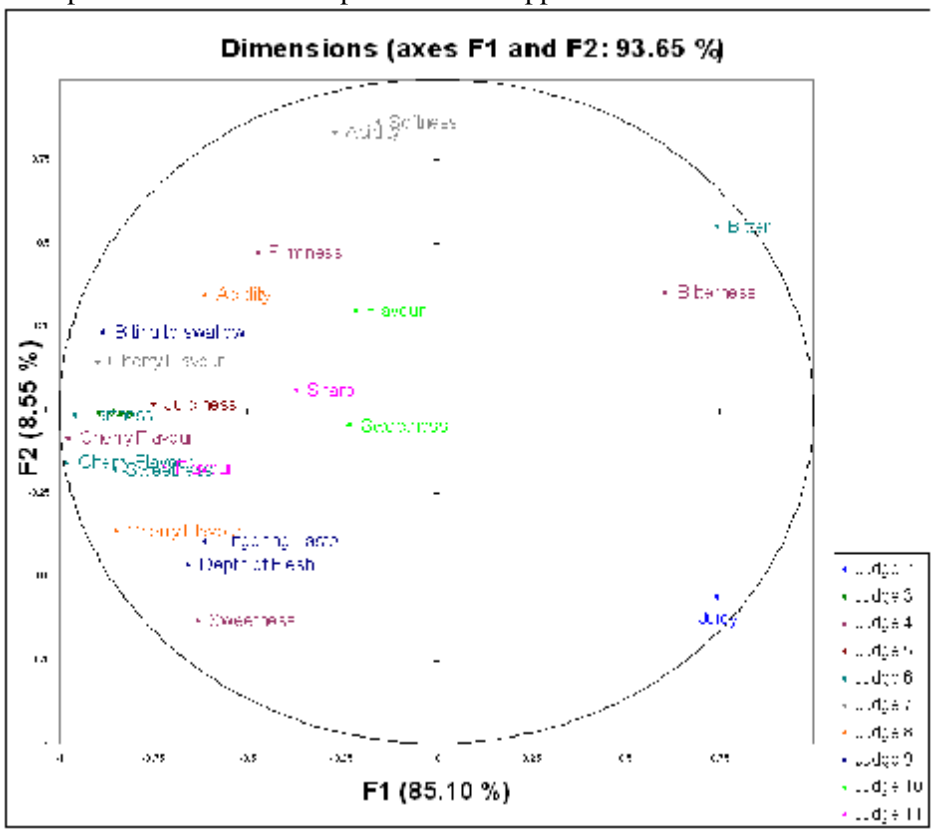
……..

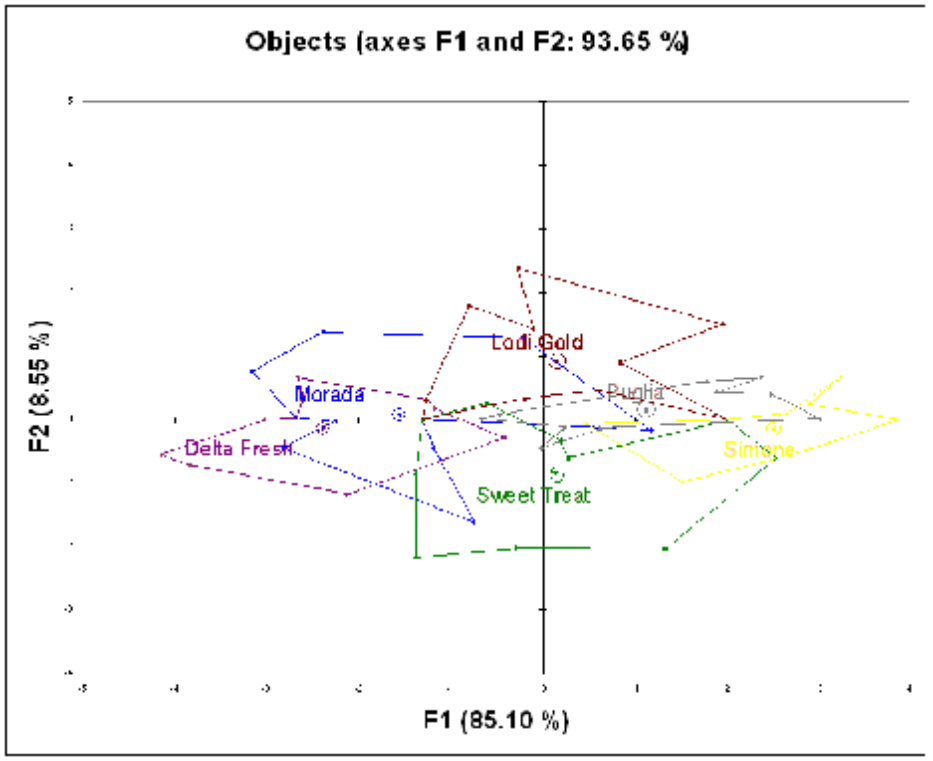
Attribute: ……

From…….. To……

Method used: ……...

GPA plots of the data in chapter 3.1 when appearance attributes were removed





The University of Nottingham

Consumer study

Judge n° :..... **Date:…….**

- You are presented with 8 samples. Please taste each sample in the order given. Rank them for preference by writing the relevant codes in the table below once you have tasted all the samples.

- You are allowed to re-taste the samples. You may rank samples as equally preferred if necessary.

Least Preferred 6	**5**	**4**	**3**	**2**	**Most Preferred 1**

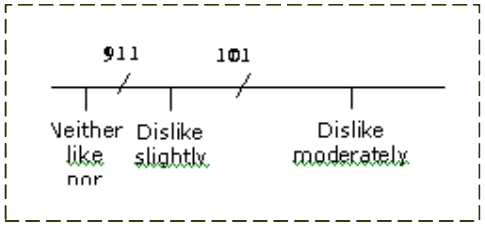
Please cleanse your palate, press the green button to indicate that you have finished and return to the lounge for a 10 minute break before the next stage.

The University of Nottingham

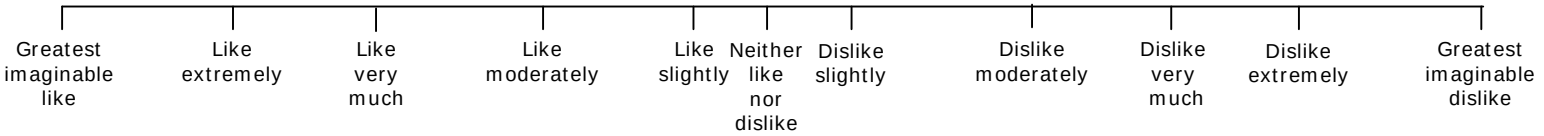
Consumer study

Judge n° :..... **Date:…….**

- Your response sheet from the previous session shows your ranking of eight samples for preference. Re-taste the samples and indicate your level of liking for each of the eight samples on the scale below. Place a mark on the line which best represents your level of liking (you can mark the scale anywhere on the line) and label the mark with the appropriate random code (see box opposite).



- Cleanse your palate between samples



- Press the green button to indicate when you have finished.

Thank you for your time