Physical, sensory and consumer analysis of pear genotypes among South African consumers and preference of appearance among European consumers

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SUMMARY

The aim of this research project was to determine the preference of pear appearance and taste among South African pear consumers using descriptive sensory analysis, consumer preference and physical maturity measurements. The preference of external pear appearance among European consumers was also established. The Agricultural Research Council (ARC) Infruitec-Nietvoorbij, South Africa, aims to breed new cultivars with a local as well as export market potential. They are focused on a range of blushed cultivars from early to late season which do not loose their skin colour. Important eating quality characteristics they are focused on are high sugar content (sweet taste) and a strong pear flavour. Both research studies performed on local South African consumers showed that these objectives align very well with consumer preference. Lightly coloured blushed pears were preferred and important sensory attributes were pear flavour, sweet taste, melt character, juiciness and a soft texture. Sour taste, astringency, mealiness and grittiness were negative attributes. The appearance preference conducted on European consumers determined that these consumers prefer a bright yellow or green colour with a light red or pink blush. Shape played a role and a typical pear shape was preferred. The outcomes of the research performed on local South African consumers were compared to results found internationally. The findings were consistent with important sensory attributes being pear flavour, sweetness and juiciness and yellow or green colours preferred or a light blush was also acceptable. Age and gender did not seem to play a role in the preference analyses. Therefore, preference studies can be conducted locally on new cultivars for the export market. Blushed cultivars are prone to red colour loss in high temperature conditions. Breeding of selections (e.g. 'Cheeky') that accumulate more red pigment and are therefore less prone to colour loss has been done to try to overcome this problem. However, these selections are redder and darker in colour and have a lower preference among consumers. A possible solution to this could be to breed light blushed pears (e.g. Rosemarie) but to market the cultivar, as is the case with Cripp's Pink apples, with separate trademark names for fruit with adequate and inadequate blush development. Thereby, the producers will still receive compensation for their produce if the colour is lost but if not, a higher premium will be received.

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OPSOMMING

Doel van hierdie navorsing was om Suid-Afrikaanse verbruikers se voorkeur vir peer voorkoms en smaak te bepaal deur gebruik te maak van beskrywende sensoriese analise, verbruikerstudies en fisiese rypheidsmeting. Europese verbruikers se voorkeur ten opsigte van eksterne peer voorkoms is ook bepaal. Die Landbounavorsingsraad (LNR) Infruitec-Nietvoorbij, Suid-Afrika, poog om nuwe kultivars te teel met beide plaaslike en uitvoermark potensiaal. Die teelprogram fokus op die ontwikkeling van ‘n reeks vroeë tot laat seisoen bloskultivars wat nie hul rooi skilkleur verloor in reaksie op hoë temperature nie. Belangrike eetkwaliteiteienskappe waarop gefokus word sluit in ‘n hoë suikerinhoud (soet smaak) en ‘n sterk peer geur. Beide navorsingstudies dui op goeie ooreenstemming tussen hierdie teeldoelwitte en die voorkeure van Suid-Afrikaanse verbruikers. Liggekleurde blospere is verkies met peer geur, soet smaak, smelt karakter, sappigheid en ‘n sagte tekstuur as die verkose sensoriese eienskappe. ‘n Suur smaak, vrankheid, melerigheid en grinterigheid was negatiewe eienskappe. Europese verbruikers het ‘n helder geel of groen skilkleur met ‘n ligte rooi of pienk blos verkies. Vrugvorm beïnvloed ook voorkeur vir voorkoms met verbruikers wat ‘n tipiese peer vorm verkies. Die voorkeure van plaaslike verbruikers was soortgelyk aan die voorkeure bepaal in internasionale studies. Belangrike voorkeur sensoriese eienskappe vir oorsese verbruikers was ook peer geur, soetheid en sappigheid terwyl ‘n geel of groen skilkleur verkies is. ‘n Ligte blos was ook aanvaarbaar. Ouderdom en geslag het oënskynlik nie die analise van voorkeur beïnvloed nie. Gevolglik kan plaaslike verbruiker gebruik word om die voorkeur vir nuwe kultivars bestem vir die uitvoermark te bepaal. Bloskultivar is geneig tot verlies van hul rooi kleur onder hoë-temperatuur toestande. Om hierdie probleem te oorkom, word kultivars geteel wat meer rooi pigment akkumuleer en dus ‘n laer geneigdheid tot kleurverlies het (bv. ‘Cheeky’). Sulke kultivars is egter rooier en donkerder van kleur en het ‘n laer voorkeur vir voorkoms onder verbruikers. ‘n Moontlike oplossing is om pere met ‘n ligte blos te teel (bv. ‘Rosemarie’), maar die kultivar soos in die geval met ‘Cripp’s Pink’ appels te bemark met verskillende handelsmerk name vir vrugte met voldoende of onvoldoende blos. Sodoende kan produsente gekompenseer word selfs al verloor die ligte blospere hul kleur, terwyl ‘n premie verdien word met vrugte met voldoende rooi kleur.

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CONTENTS

The language and style used in this thesis are in accordance with the requirements of the *International Journal of Food Science and Technology*. This thesis represents a compilation of manuscripts in which each chapter is an individual entity and some repetition between chapters has, therefore, been unavoidable.

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CHAPTER 1

General Introduction

The pear industry in South Africa is an important sector of the deciduous fruit industry. The main cultivars produced in South Africa are Packham's Triumph (29% of total production), Bon Chrétien (20%), Forelle (24%), Early Bon Chrétien (9%), Beurre Bosc (4%) and Doyenne du Comice (3%) (DFPT, 2008). More than one third (38%) of the total crop is exported for fresh consumption, 44% is processed and 18% is sold fresh locally (Ferrandi *et al*., 2005). The main export destinations are the European Union (61%) and United Kingdom (20%) (DFPT, 2008). It is important for South Africa to stay competitive on the overseas markets as such a large volume of production (approximately 162,360 tons) is exported and exports have almost doubled over the past decade (Ferrandi *et al*., 2005). The large amount of consumption locally means the preference of South African consumers must also be understood.

The red blushed cultivars, Forelle, Flamingo and Rosemarie, increased in importance during the late 1990's due to the higher amounts that consumers were willing to pay for these attractive fruit (Human, 2002). These cultivars were harvested from early to late season thereby providing South Africa with a strong marketing advantage (Human, 2002). Due to various reasons including sensitivity to temperature causing a decrease in red pigmentation (Steyn *et al*., 2004), production of 'Rosemarie' and 'Flamingo' decreased and only 'Forelle' is still produced in substantial quantity (Human, 2005). An early season replacement is therefore necessary to fill this gap.

The pear breeding program of the Agricultural Research Council (ARC) Infruitec-Nietvoorbij in Stellenbosch, South Africa, currently focuses on breeding a range of blushed selections from early to late with good eating and storage qualities, developing new blushed selections that do not loose skin colour during high temperature conditions, improving and replacing existing cultivars and breeding of new unique pear cultivars for the future (Human, 2008). The consumer preference for cultivars with a deeper red blush, in order for it not to lose its colour, is not yet known. Sensory analysis plays a large role in supporting the breeding and introduction of new cultivars into the marketplace (Hampson *et al*., 2000) and can be used to understand the colour preferred by the consumer and the effect colour has on the perception of internal qualities.

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Eating quality of fruit is difficult to measure objectively. Sensory analysis is therefore used in defining sensory attributes relating to consumer preference such as texture, especially juiciness, taste (sweetness) and aroma (typical of cultivar), all of which are important determinants of eating quality in pears (Eccher Zerbini, 2002). In general, European pears with a good eating quality have a juicy, buttery and melting texture with a good pear flavour (Eccher Zerbini, 2002). However, there are consumers that prefer pears with a crispy and juicy texture to a buttery and melting one (Hoehn *et al*., 1996).

This study was undertaken in collaboration with the Departments of Horticulture and Food Science at the University of Stellenbosch, South Africa. There were three separate research projects in this study. The first investigation was undertaken during 2007 (Figure 1.1) to determine the effect of the appearance of eleven pear genotypes, including established cultivars and selections from a breeding program, on preference among consumers. Using peeled and unpeeled samples of the same pear cultivars, the consumer's preference of taste was measured. The second study was carried out during 2008 (Figure 1.2) and was similar to the first but with the emphasis on preference of eating quality. The samples were left unpeeled and eleven different genotypes were analysed. More commercial cultivars with known eating qualities were included than previously. The last section took place in 2008 and investigated the preference of appearance of 16 pear genotypes presented on photographs among European consumers. The amount of money the consumers were willing to pay for each pear genotype was determined and the effect of colour on the overall appearance was investigated.

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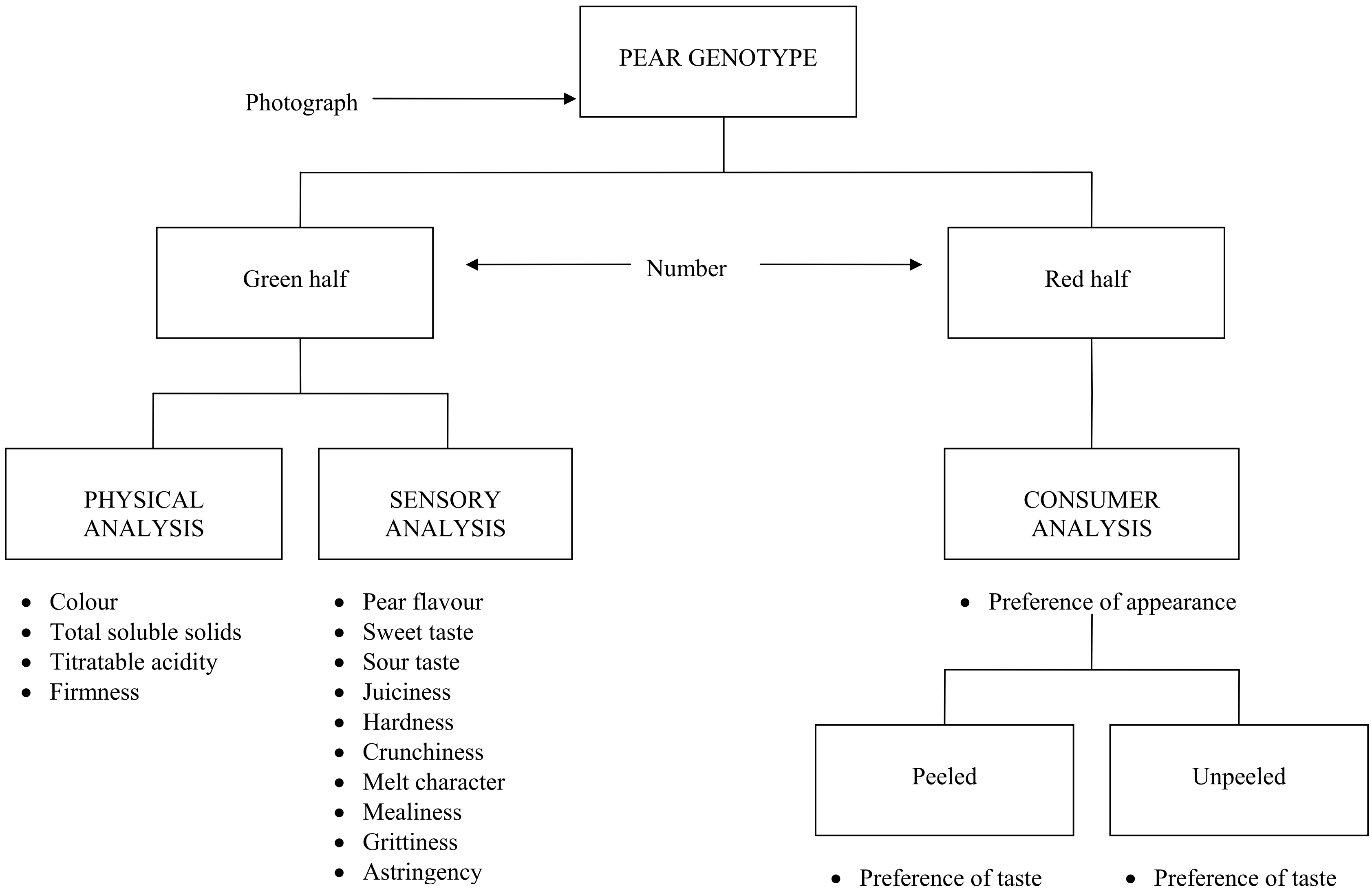

Figure 1.1 Research framework of pear genotypes during 2007

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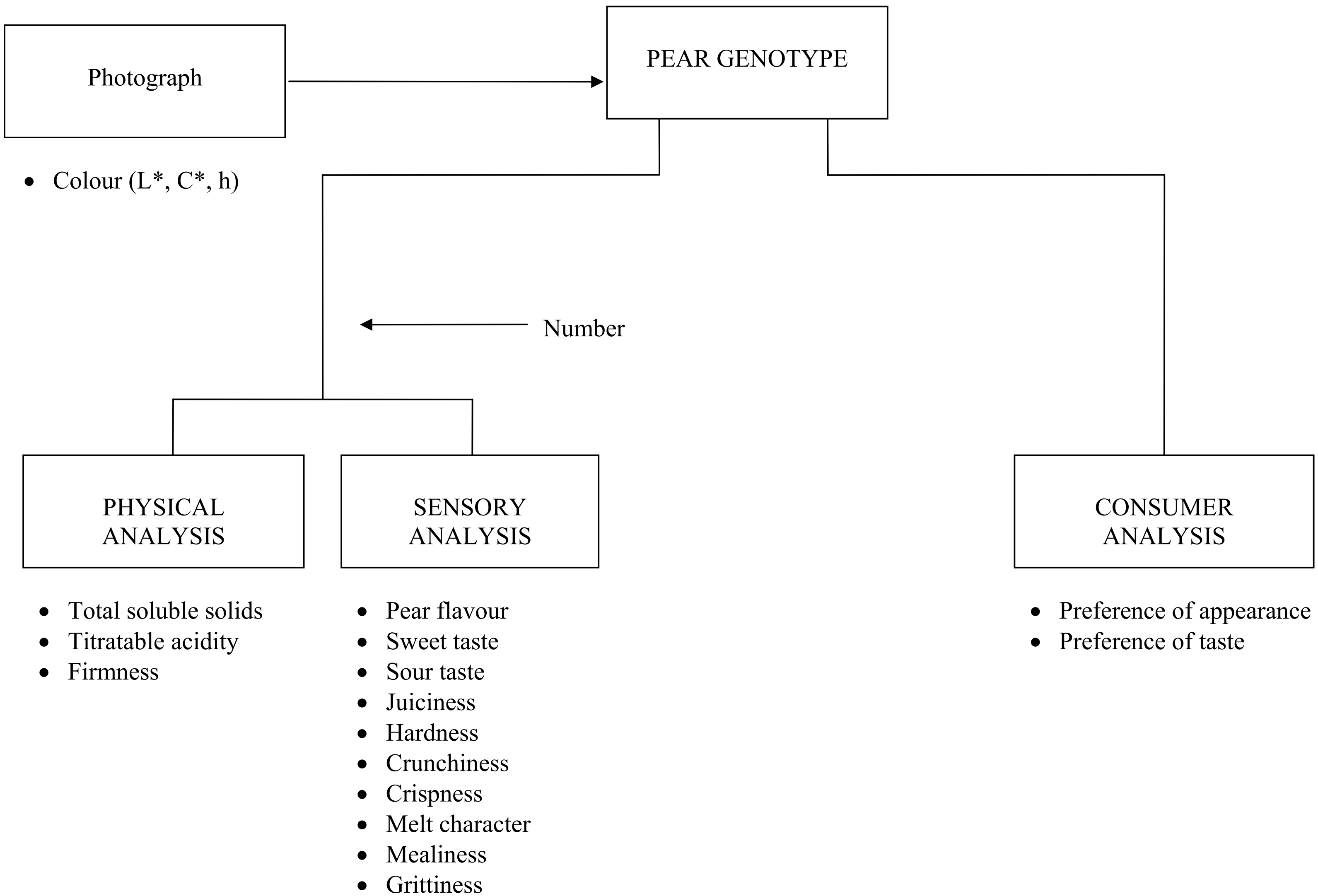

Figure 1.2 Research framework of pear genotypes during 2008

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CHAPTER 2

Literature Review

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INTRODUCTION

Expectations of liking play an important role in food analysis (Cardello, 1994). The appearance of a product, especially the external colour, can thus have a major effect on potential consumers. The colour of fruit can be a quality factor which can influence the selection of a certain cultivar, the purchase of the fruit and lastly, the consumption by the consumer. The general appearance also establishes expectations of what the fruit may taste like (Cardello, 1994). If the consumer does not like the external appearance of the fruit, it is unlikely that they will then taste the fruit and further judge the flavour and texture (Jaeger *et al.*, 2003). If the consumer has previously purchased a certain cultivar or fruit, they would already be aware of its taste and texture, but if not, the appearance together with the aroma and any other physical indications, are the only sensory attributes available for the consumer to make a decision. The importance of this is proved by the actions taken by the fruit industry to ensure that the fruit in the retail stores are of a standardized appearance (Jaeger *et al.*, 2003).

Pears are available in a wide range of colours, i.e. yellow, green, brown and red. These colours are derived from three pigment groups: chlorophyll, carotenoids and anthocyanins. The colour of the fruit results from the concentration and distribution of these pigments within the skin (Lancaster *et al.*, 1994). Pears with a red or blush colouring contain predominantly anthocyanins in the peel (Francis, 1970). Blush pears have a ground colour such as yellow or green with a red colouring covering a percentage of the peel, for example 'Rosemarie'.

Pears with a red colouring, or blush, are generally not easily found in certain marketplaces (Jaeger *et al.*, 2003), despite an increased demand for blushed coloured pears worldwide. 'Rosemarie' was a blush pear cultivar released to the South African pear industry in 1990 by the pear breeding programme of Agricultural Research Council (ARC) Infruitec-Nietvoorbij in Stellenbosch, South Africa. After this in 1993, 'Flamingo', which is another blush cultivar, was released. 'Rosemarie' is harvested early in the season (January), followed by 'Flamingo' (February). 'Forelle' was the already existing blush pear which is a later-ripening cultivar (February to March). This range gave South Africa a strong marketing edge as the only supplier of blushed pears to the European market (Human, 2002). Up to three times more money is paid for blushed compared to standard green pear cultivars (Human, 2005; DFPT, 2008). This was the driving force for South African pear producers to plant blush cultivars instead of conventional, green cultivars (Human, 2002). The production of

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'Rosemarie' and 'Flamingo' has decreased significantly over the past few years. A major reason for this is the sensitivity of these cultivars to high temperatures that have a negative effect on the development of the blush colour (Steyn *et al*., 2004). Lightly blushed cultivars are most prone to colour loss prior to harvest. The ARC breeding program is aiming to develop new cultivars with a deeper blush that is less likely to lose its colour (Human, 2007). However, the consumer preference for selections with a darker blush is not known. It is therefore important to understand the colour preferred by the consumer and the effect colour has on the perception of internal qualities. This can be determined by conducting standard sensory analyses and/or consumer preference for different pear cultivars. ARC Infruitec-Nietvoorbij is currently analysing the performances of pear selections compared to that of cultivars already released. The focus is on identification of potential new pear cultivars with good marketing potential, external and internal fruit quality and adaptability in a Mediterranean-type Western Cape climate. When new pear cultivars are considered for release, it is important that they show improved characteristics in comparison to similar, traditionally produced cultivars (Human, 2007).

Sensory analysis plays a large role in supporting breeding and introduction of new cultivars into the marketplace (Hampson *et al*., 2000). However, it is important to note that a product will not necessarily be financially successful because it had an overall higher degree of liking from a sensory perspective. Success in the market place is also affected by many other factors including price, market image, packaging and niche (Lawless and Heymann, 1999).

This chapter provides an overview of the current production trends of pears in South Africa and the rest of the world, as well as the quality characteristics and consumer acceptability of different pear types (and other fruit) regarding their appearance, flavour and texture.

TRENDS IN PEAR PRODUCTION

International

The production volumes of the main pear producers in the world for 2006 are shown in Table 2.1 (DFPT, 2008). China is the world's largest producer of pears, consisting mainly of *Pyrus pyrifolia* (Anon., 2006) whereas the European pear (*Pyrus communis* L.) is produced in the Western areas of the world. World pear production has increased over the past years because

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of the increase in production in China, but it has been stable in southern Europe, and the Oceania regions. Production has been decreasing in eastern and central Europe. It is predicted that the overall world production will continue to increase (Segrè, 2002). The consumption of fresh pears had a low growth rate (1.3%) throughout the world during 1998 – 1999, but from then on the consumption began to increase as the awareness of healthier eating habits grew and the World Health Organization promoted an increase in fruit and vegetable consumption to reduce risk of chronic diseases (Anon., 2003). Pears have a low content of cholesterol and kilojoules, and high fibre and vitamins (Dussi *et al.*, 1998).

Table 2.1. Volume of production of major pear producing areas of the world for 2006. Source: DFPT (2008).

Production area	**Volume (tons)**
World	19,534,480
China	11,988,000
Italy	907,458
USA	757,780
Spain	590,000
Argentina	509,749
Japan	319,100
South Africa	316,133
Netherlands	222,000
France	220,185
Belgium	215,000
Chile	212,000

Northern hemisphere

The pear production in Asia has increased since 1990 especially in China, Korea, Turkey, India, and Iran (Saito *et al*., 2005). This is due to high profitability, increasing consumer demand, and improvement in production methods. Asia has also changed from importers to exporters of pears (Gemma, 2002). China contributes 90% of the pear production in Asia, making this country by far the largest producer in the region. China is also the world's largest pear producer. The cultivars are mainly crisp-fleshly pears, which belong to *P. bretschneideri* and *P. pyrifolia* (Saito *et al*., 2005). In 2001/02 it was forecast that China's production would

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reach a record of nearly 9 million tons. China's exports increased from almost nothing in 1990 to about 41,000 tons in 2000. The fruit quality produced continues to improve which adds to the expansion of their exports to Southeast Asia and Russia (Gemma, 2002). Japan is also a large producer of pears with 368,200 tons in 2001. Pears are the third most cultivated fruit after apples and citrus in Japan (Saito *et al*., 2005).

Pear production is a minor part of fruit production in Northern Europe, contributing to only between 5 and 15% of pome fruits and the breeding of pears is limited although the Netherlands and Belgium have reported increases in production (Bünemann, 2002). Countries in the European Union supply about 25% and non-European Union countries, such as South Africa, Argentina, and Chile, supply the remaining 75% of pear volumes to northern Europe (Mazzotti *et al*., 2002). Pear imports for the Netherlands are usually approximately 100,000 tons. The pear production in southern Europe is mainly in Italy, Spain and France. Italy and Spain are the most important pear producing countries with 65% of the total European production (Deckers and Schoofs, 2005). The most prevalent cultivars in Europe are Conference (25%), Williams Bon Chrétien (11%) and Abate Fetel (10%). The introduction of red pear cultivars was not a success (Deckers and Schoofs, 2005).

Pears are one of the most important fruit crops grown in the Pacific Northwest region of the United States (Suwanagul and Richardson, 1998). Most of the United States' pears (97%) come from Washington, Oregon and California (Suwanagul and Richardson, 1998). Two-thirds of the pear production is processed and the rest consumed in the fresh market (Seavert, 2005). Williams Bon Chrétien (42%), d'Anjou (33%) and Bosc (8%) are the main pear cultivars grown in these areas (Ing, 2002; Seavert, 2005).

Southern Hemisphere

The main countries of pear production in South America are Argentina and Chile, contributing to 90% of the total area (Sanchez, 2002). Argentina's pear production is the largest in the Southern Hemisphere and contributes 4% to the world's production (Dussi *et al*., 1998). Nearly 20% of this fruit is used in their domestic market and the rest is exported as fresh fruit or concentrated juice (Sanchez, 2002). The most widely planted cultivar in Argentina is 'William's Bon Chrétien' (50%), followed by 'Packham's Triumph' (27%) and 'Beurre d'Anjou' (10%) (Sanchez, 2005).

Chile is the second largest exporter in the Southern Hemisphere (Sanchez, 2002). They export mainly to North America (25%) and Europe (25.5%) (Yuri and Torres, 1998).

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'Packham's Triumph' accounts for about 45% of the total Chilean pear production and 'Beurre Bosc' makes up about 25% of the pear production and exports (Sanchez, 2002).

South Africa is the third largest exporter in the Southern Hemisphere (Human, 2007). Countries in the European Union are of South Africa's major export markets (Human, 2007). The African continent, however, is a very small producer of *Pyrus communis* pears. In the global context, Africa only comprises 3% of global hectares and production. South Africa produces 56% of Africa's total crop, followed by Algeria (16%), Tunisia (11%), Egypt (9%) and Morocco (8%) (Ferrandi *et al*., 2005).

South Africa

In South Africa, the pear industry is the fourth largest fruit industry, exceeded by apple, citrus and grape (White *et al*., 2002). Pears are a minor product compared to the total fruit crop in South Africa, representing only 6% of the total fruit production. However, the pear industry is very important in terms of export and economic impact for South Africa, especially the Western Cape and Eastern Cape provinces. A total 13,572 ha is used for the production of pears; this comprises 21% of the total area used for deciduous fruit production (Human, 2002), and exports amounted to ± 10 million cartons in 2003 (Ferrandi *et al*., 2005). The planted area has increased over 40% from 9000 to 13000 hectares in the last ten years and production increased by 50%. South Africa exports 38% of the crop to European markets (Ferrandi *et al*., 2005). Packham's Triumph is one of the main fresh export cultivars but there has been much emphasis on blushed cultivars such as Forelle, Rosemarie and Flamingo over the past 15 years, with high returns to growers, especially with Forelle (Ferrandi *et al*., 2005). Due to a lack of adequate colour in these blushed cultivars (Ferrandi *et al*., 2005) the production of 'Rosemarie' and 'Flamingo' has in the meantime decreased. Figure 2.1 depicts the area used for the different pear cultivars in South Africa (DFPT, 2008).

Pears are planted in most of the deciduous fruit producing areas of South Africa; Ceres is the most important region (54%), followed by Elgin (19%) and Langkloof (9%) (Human, 2005). Most of the fruit is exported for the desert market, but a large portion, mostly Bon Chrétien (32%) is canned (Human, 2002). The utilization of pears in South Africa is shown in Table 2.2 (DFPT, 2008).

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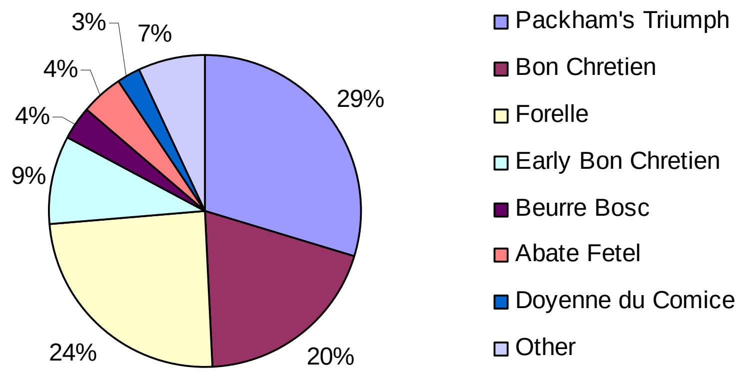

Figure 2.1. Pie chart of area planted to different pear cultivars in South Africa. Source: DFPT (2008).

Table 2.2 Utilization of pears in South Africa for 2006/2007. Source: DFPT (2008).

Crop utilization	**Volume (tons)**	**%**
Fresh consumption (local)	57,931	17
Fresh consumption (export)	162,360	47
Processed	118,780	34
Dried	8,592	2
Total	347,763	100

At present, the main emphasis of the pear breeding program in South Africa is to develop a full range of blushed and full-red cultivars with good eating taste and quality (Human, 2007). It is important that these cultivars produce a good quality fruit with an attractive colour because of the uniqueness of these blushed cultivars to the South African pear industry (Human, 2002).

QUALITY CHARACTERISTICS OF FRUIT, PREDOMINANTLY PEARS

Fruit quality includes many properties such as sensory attributes (appearance, texture and flavour), nutritional value, chemical constituents, mechanical properties, functional properties and defects (Abbot, 1999).

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Appearance

External factors of the appearance of fruit, such as shape and colour, can have a large influence on the consumer's first impression and opinion of what the fruit may taste like (Jaeger and MacFie, 2001). Therefore, one can say that appearance and colour are primary indicators of perceived quality (Lawless and Heymannn, 1999). Colour is probably the most important appearance characteristic of foods, especially if some other aspect of quality is related to the colour. An example of this is the ripening of fruit or the colour changes which occur with deterioration and spoilage (Lawless and Heymann, 1999). The final judgement of fruit quality is then made only once it has been tasted (Kingston, 1991).

Pears can have a variety of different skin colours including yellow, green, brown or russet and red (Kappel *et al*., 1995). Blush pears have a ground colour of yellow, green or brown with a red blush covering part of the peel. The shape of pears can range from round to elongate (Kappel *et al*., 1995). Terms such as pyriform, elongate-concave and intermediate straight can also be used as when describing the intermediate shape of pears (Gamble *et al*., 2006). As already mentioned, the red colouring of pears is caused by anthocyanin pigments (Francis, 1970). Anthocyanins have the ability to produce a wide variety of colours in plants such as red or purple under favourable conditions. The general pattern of anthocyanin distribution in red pears is a non-pigmented epidermis and one or two non-pigmented hypodermal layers which lie above two to five layers containing anthocyanins (Dayton, 1966).

The chlorophyll in a pear's peel is lost as the pear mature (Kingston, 1991). Red and blushed varieties reach their reddest point while they are still unripe, but thereafter the red colour fades towards harvest (Dussi *et al*., 1997). The blush that develops depends on light exposure that is received by the fruit (Kingston, 1991) and climatic conditions such as temperature (Steyn *et al*., 2004). Apples on the outer edge and the upper portion of the canopy develop more of the red colour than fruit from the inner and lower portions (Heinicke, 1966). Blush fruit can cause a lot of confusion with consumers when trying to assess the ripeness of the fruit based on the skin colour changes. In a study done by Richardson-Harman *et al*. (1997), consumers considered apples with a yellow background colour and with more blush coverage as being riper than apples with a green background. What is interesting is that the background colour can be used as a ripeness indicator but not the amount of blush. In a later study, fruits with 66 to 100% blush coverage were considered to be overripe even though they were at optimal maturity (Richardson-Harman *et al*., 1997). The external colour change in some pears is not a good ripening indicator because the yellow colour may have been

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attained before the ripening and softening commenced. This occurs especially when pears have received previous long-term cold storage. Furthermore, some pear cultivars do not change skin colour during ripening (Villalobos-Acuna and Mitcham, 2008).

Various scientific studies have also shown that the colour of the product affects our perception of other attributes, such as flavour (Lawless and Heymann, 1999). For example, a picture of a 'Red Delicious' apple could be associated with a sweet taste and a green 'Granny Smith' apple could give the expectation of a sharp taste (Jaeger and MacFie, 2001). These expectations are formed from previous experiences of consuming apples. In many cases, this learned information is used by consumers to predict the flavour or texture of other fruit based on the skin colour.

Flavour

It is specifically important that fresh fruits have an excellent external appearance in addition to good flavour and texture (Suwanagul and Richardson, 1998). The flavour of a food product includes the olfactory sensations caused by volatile substances released from the product (aroma), gustatory sensations (taste) and trigeminal sensations such as astringency (Meilgaard *et al*., 1987). It is, however, well known that the colour and texture of food products can also influence the overall judgment of a particular flavour (Redgwell and Fischer, 2002).

The flavour of pears varies with the cultivar. Fruit flavour results from the combination of sugars, acids, and astringent and aromatic materials within the fruit (Kingston, 1991). An important aspect is the sweet and sour balance found in pears (Eccher Zerbini, 2002). Sweetness and sourness are due to the composition of soluble sugars and organic acids and the volatile substances are very important for quality as they convey the typical character to the flavour, and make a pear taste like a pear (Eccher Zerbini, 2002). The organic acid content of pears decrease during the maturation, ripening and storage, but generally, the acid content of pears are low and therefore have a lower impact on the flavour quality (Kingston, 1991). The composition of organic acids in pears is more varied than that of sugars. Generally, malic acid is the most widely found organic acid in all cultivars (Eccher Zerbini, 2002). Citric, quinic and shkimic acids are also major organic acids found in most pear cultivars (Chen *et al*., 2007). The soluble solids content of the fruit can be used as a quality measurement. The soluble solids increase as the pears mature because of the starches that are converted to sugars. This increases the perceived sweetness and therefore changes how the fruit tastes (Kingston, 1991). The composition of sugars is quite consistent in different pear

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cultivars. The main sugar is fructose (54 – 63%), which is 1.5 times sweeter than sucrose (Paillard, 1990). Sorbitol accounts for 22 – 31%, glucose for 11 – 15% and sucrose for 4 – 5%. During ripening, sucrose increases and sorbitol decreases without changing the Brix value (Drake and Eisele, 1999).

Aroma is one of the most important sensory attributes of fruit (Zhang *et al*., 2008). It has been found that there are close correlations between pear aroma and flavour which indicates the importance of volatile aromatics to flavour as they make a pear taste like a pear (Eccher Zerbini, 2002; Quamme and Marriage, 1977). Pear aroma can be influenced by a number of factors. These include genetic differences, preharvest factors, maturity at harvest, storage conditions, and fruit physiology (inter-fruit volatile localization, ripening, senescence and presence of disorders) (Rapparini and Predieri, 2002). Pears have a highly distinctive flavour due to their specific volatile organic compounds. Rapparini and Predieri (2002) studied the volatile compounds emitted by fresh pear flesh of different cultivars. The method used was the dynamic headspace for the analysis of the qualitative and quantitative flavour patterns of fruits under aerobic conditions. The volatile compounds emitted varied with cultivar, each showing a basic pattern. More than 40 compounds were identified. The volatile profiles are characterized by compounds in groups of esters, alcohols, hydrocarbons, aldehydes and ketons. Acetate esters comprised the largest portion (more than 70%) of volatiles emitted by the pear fruits analysed; butyl alcetate, propyl acetate, hexyl acetate and amylacetate were produced in the largest amount. In all the screened cultivars, decadienoate esters were also detected. These have been shown to be character impact compounds (Rapparini and Predieri, 2002). In a similar study done by Suwanagul and Richardson (1998), the headspace volatile compounds of eight different pear cultivars that were ripened optimally were determined. The volatile profiles of the cultivars studied were characterized by 112 compounds in groups of esters, alcohols, hydrocarbons, aldehydes and ketones. Esters were also present as a major group of compounds. Hexyl acetate was found to be a contributory flavour compound in pears.

Texture

Texture was defined by Szczesniak (1990) as “the sensory manifestation of the structure of the food and the manner in which this structure reacts to the applied forces, the specific senses being involved being vision, kinaesthesia, and hearing”. It is an important quality attribute of fresh fruit and vegetables, however, flavour often overshadows the texture of a product (Nicolai *et al*., 2003). Consumers simply take the texture of a food for granted, considering it an essential part of the nature of the food (Szczesniak and Kahn, 2007). A strong interaction

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appears to exist between texture and flavour; the blander the flavour, the greater the awareness of texture (Szczesniak and Kahn, 2007).

Ripening is the key factor for fruit texture and thus ultimately fruit quality. The most apparent change occurring during ripening is loss of firmness (Eccher Zerbini, 2002). As the pear ripens, the middle lamella, the cementing material between the cells, dissolves and together with changes in the cell sap cause the fruit to soften. This change is mostly noticeable with an increase in soluble polyuronides and a decrease in insoluble polyuronides (Yoshioka *et al*., 1992). Pears with good quality develop a buttery and juicy texture which is associated with an increase in extractable juice. This probably results from an increase in solubility of polyuronides in the pulp (Chen and Mellenthin, 1981). Fruit that is harvested either before or after the optimum harvest dates do not ripen normally and never develop the characteristic buttery and juicy texture of ripe fruit (Ben-Arie and Sonego, 1979; Wang, 1982). Firmness values obtained with a penetrometer can be used to determine the optimum harvest time for pears. Fruit firmness is highly correlated with overall quality and texture (Kingston, 1991), and is a good indicator of fruit crispness and juiciness. Firmness, as measured by a puncture test, is probably the most reliable indicator of maturity (Crassweller, 2006), yet firmness is only one of a group of properties that constitute texture (Bourne, 1979).

Texture after ripening is dependent on maturity at harvest, length and type of storage, ripening conditions and their interactions (Eccher Zerbini *et al*., 1998). The conditions the fruit are stored and ripened in have a big influence on the quality, especially texture. Texture affects release of juice and the availability of acids, sugars and volatile substances in the mouth. This determines the flavour of pears (Eccher Zerbini *et al*., 1998). Texture is therefore a critical feature of pear quality because it allows these compounds contained in the cells to be removed with chewing and so they can then be perceived by the consumer (Eccher Zerbini, 2002). Chen *et al*. (1983) measured the ripening behaviour of 'D'Anjou' pears after cold storage. They found that the same amount of softening as measured by pressure test can correspond to different types of texture. In these pears stored at -1.1 ºC for 1 to 8 months, sensory quality was evaluated after ten days of ripening at 20 ºC. Fruit stored for 2 to 8 months softened about the same during ripening. Fruit stored one month softened at a slower rate, with a coarse and dry texture. Fruit stored 2 to 4 months had a buttery and juicy texture. Fruit stored longer than 5 months had a coarse dry or mealy texture. Flavour was produced about one month later than buttery and juicy texture, and it seems to be related to the synthesis of volatile esters rather than to cell wall metabolism (Chen *et al*., 1983).

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For most fruit 'juiciness' is a principal texture attribute. Consumers often expect fruit to provide the sensation of juiciness irrelevant of whether the product has crisp/hard texture as in an apple, or a soft/melting texture as in a peach (Harker *et al*., 2003).

Another aspect of texture is the skin or peel of the fruit. The skin could influence the sensory properties of fruit in a number of ways (Amos, 2007). The effort needed to bite into the flesh could be influenced. The skin contributes to the texture while chewing and breaking down of the flesh as well as contributing to the flavour particularly, sweetness, bitterness, and astringency. The influence of the skin could also, on the other hand, be small as it represents only a small proportion of the total fruit volume (Amos, 2007).

CONSUMER ACCEPTABILITY OF FRUIT

Sensory analysis has been defined as "a scientific discipline used to evoke, measure, analyse, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing" (IFT, 1975). Colour relates directly to consumer perception of appearance. Pigment concentration may be more directly related to maturity and concentration of certain other constituents relates more closely to flavour (Abbott, 1999).

Traditionally in a consumer sensory analysis, the consumers are not asked to answer any written questions while completing a preference test but asking consumers what they expect from a product can have many beneficial results. In a survey done by Jaeger *et al.* (2003), New Zealand consumers were asked to describe their ideas on what they perceive as the ideal pear. The same consumers completed a sensory acceptability analysis using a nine point hedonic scale and a set of seven pears were presented to them to be ranked in terms of appearance. The sentence completion responses for the 'ideal' colour of pears proved that green, yellow and brown pears were the choice for consumers. With regard to texture, it was mentioned that the fruit should be not too soft and still juicy and crisp. This could be due to the familiarity with *P. pyrifolia* which is widely available in New Zealand. There was a preference for medium to large pears (Jaeger *et al*., 2003). In a similar study done by Kappel *et al.* (1995) with Canadian consumers, the ideal pear had a yellow skin colour, a low firmness and a sweet taste with slight sourness (Kappel *et al*., 1995). This was similar to the results of the study done by Turner *et al*. (2005) with American consumers. Yellow was the colour of preference and a 'Bon Chrétien' shaped was preferred. Sweetness and pear flavour

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were also the most important taste attributes. Predieri *et al*. (2005) found that sweetness, aroma and juiciness had the highest correlation with overall liking among Italian consumers.

The colour of fruit can also have an influence on a consumer when deciding on the purchasing or consumption of the fruit. An expectation is formed from previous experience of what the colour of the fruit should be when it is at optimal maturity. The relationship between cherry skin colour at harvest and consumer acceptance was investigated by Crisosto *et al.* (2002). A trained panel of 15 members evaluated the sensory perception of sweetness, sourness and cherry flavour intensity. The consumers were each asked to wear dark glasses when tasting the samples and their acceptance was measured as a degree of liking and a percentage. The trained judges perceived an increase in sweetness and cherry flavour intensity with each successive skin colour, from full light to full dark red. The perception of sweetness, sourness and cherry flavour was highly correlated to skin colour, soluble solids concentration and the ratio of soluble solids concentration to titratable acidity at harvest. The consumer acceptance was related to cherry skin colour as the cherries harvested at the full light red colour had the lowest ratings and those at full dark red had the highest.

Calvo *et al.* (2001) studied the influence of colourant concentration on the perception of flavour and sweetness in four flavours of yoghurts. The sensory panel of 25 assessors each received five samples of each of the flavoured yoghurts per session and evaluated them for intensity of taste and sweetness on an unstructured scale. The samples had the same amount of sugar and flavouring but the greater the concentration of the colourant, the greater the perceived fruit flavour for the strawberry, orange and fruit of the forest flavours, but not the lemon flavour. With the fruits of the forest flavoured yoghurt it was found that the perceived sweetness increased with the increase of colourant.

Consumers may use the appearance of a food product as an expectation for sensory quality. For example, if a ‘Red Delicious’ apple is viewed, it may be associated with a sweet taste but a ‘Granny Smith’ apple may be associated with an acidic taste (Jaeger and MacFie, 2001). The consumer’s expectation for a new variety of apple was examined using differing advertising content and format by Jaeger and MacFie (2001). The consumers were presented with advertisements containing only text and advertisements containing both text and pictures. This resulted in two different expectations. The advertisements with the text and the pictures lowered expectations of juiciness and liking as well as the purchase intention. This shows that the pictures had a negative influence on the consumers. The pictures of the apples were mostly red which could be the reason for the lowering of expectations. The

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consumers could depend on the colour of apple that they are familiar with and those they normally would eat.

Cross-cultural differences in consumer preferences can also be linked to familiarity among culturally distinct populations. For example, a study done by Bertino *et al*. (1983) tested the preference of cookies and a salty aqueous solution among students in the United States and Taiwan. The American students gave higher preference ratings to the cookies because they were more familiar with this type of product than the Taiwanese students. On the other hand, the Taiwanese students gave a higher preference for salty solutions, such as soy sauce, as they were familiar with this type of product in their cuisine (Bertino *et al*., 1983).

The qualitative aspects of pear flavour were analysed by Russell *et al*. (1981) by conducting a sensory analysis to assess taste and aroma acceptability of 11 varieties of pears. Ultraviolet spectroscopy, liquid and gas chromatography confirmed the qualitative and quantitative differences in volatile flavour constituents of 'Bartlett', 'Magness' and 'Kieffer' pears. 'Bartlett' pears received the highest consumer flavour panel scores. The gas chromatography of 'Bartlett' pears also indicated that they contain the largest and greatest concentrations of flavour constituents and from ultraviolet spectroscopy it can be concluded that they contain much greater quantities of decadienoates (Russell *et al*., 1981). No correlations were performed in the study but a correlation could result between the consumers' sensory scores and the number of volatile constituents in pears or the concentration of decadienoates.

Szczesniak and Bourne (1969) conducted a sensory analysis of food firmness without allowing the consumers to eat the products. The products were presented in pairs and ranged from dairy products to fruit and vegetables. 'Bosc' pears were included in this study and a half-ripe sample was compared to an unripe sample. The 131 consumers were asked to determine by non-oral methods which sample in the pair had a higher firmness. The type of sensory test used to judge the firmness depended on the level of firmness in the test sample. The puncture test was used almost exclusively on the pear samples. The consumers pressed with the thumb until they felt the flesh yield. Contrary to what is normally believed, a built in bias due to colour and apparent freshness of the food had very little effect on the decisions made. Only two consumers used appearance only when analyzing the pears, saying that the green pear was more firm than the yellow-green pear.

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In a study done by Christensen (1983), consumers judged the aroma, flavour and texture of foods that were normally coloured and those that were either uncoloured or inappropriately coloured. In general, the appropriately coloured foods were perceived to have a stronger intensity and better quality aroma and flavour. The judgements of the texture were not affected by the colour manipulations (Christensen, 1983). The texture and appearance of fruit are judged subjectively by the consumer and it seems natural to use similar judgements on research on fruit quality (Redgwell and Fischer, 2002).

SUMMARY

The pear is a well-known temperate fruit popular throughout recorded history in the West and the East (Janick, 2002). Pears are available in a wide range of colours (Kappel *et al*., 1995), but in South Africa, the production of the blushed 'Forelle' pears is of high importance. These unique fruit fetch higher prices than the conventional green cultivars but it is important that they produce top quality fruit with a good and attractive colour (Human, 2002) and it is important to stay competitive on overseas markets by developing new, climatically adapted cultivars (Human, 2005). New cultivars, especially ranges of new cultivars, with harvest dates from early to late in the season, can fill gaps in the marketing strategy of exporters and in the local markets (Human, 2005).

As appearance and eating quality are difficult to measure objectively, fruit breeders rely on sensory assessment to identify the most promising phenotypes among progenies derived by controlled crosses (Bell *et al*., 1996; Hampson *et al*., 2000). The correct use of these sensory assessments may provide tools for better understanding the role of sensory traits in consumer acceptance and overall quality analysis, leading to consistent purchase choices (Predieri *et al*., 2005).

In conclusion, visual sensory properties, such as colour and shape, are of critical importance. This is especially true where products are sold largely through appearance properties rather than through packaging, such as fruit (Imram, 1999). However, consumer perception of fruit quality is influenced by visual as well as sensory qualities. Therefore, both of these indicators must be considered when measuring fruit quality. The most commonly used measurable indices are titratable acidity, soluble solids concentration and flesh firmness. The sensory traits that are important in pears are juiciness, sweetness, acidity, aroma, astringency, flesh texture and firmness (Kappel *et al*., 1995; Prederi *et al*., 2002). The flavour includes the olfactory sensations caused by volatile substances released from the product

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(aroma), gustatory sensations (taste) and trigeminal factors such as astringency (Meilgaard *et al*., 1987).

Consumer acceptance is the essential 'bottom line' information for product developers and marketers. A number of useful methods are available to assess the appeal of products and the relative preferences among a set of choices. Choice itself is fundamental to consumer behaviour, as it is the decision process that we all make when faced with a number of different foods for purchase or use in a meal. Acceptance can be related to other properties of foods such as the descriptive profile of a product or to physical ingredient, processing, and packaging variables (Heymann and Lawless, 1998). The sensory appeal is needed for a product to succeed. This platform of sensory-based acceptance provides the foundation for successful marketers to then apply their artistry to sell the product to consumers in the real world (Heymann and Lawless, 1998). In general, pears with good eating quality have juicy, buttery and melting texture with a good pear flavour. However there are consumers that prefer pears with a crispy and juicy texture to a buttery and melting one (Eccher Zerbini, 2002).

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CHAPTER 3

Consumer preference of pears with emphasis on colour

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ABSTRACT

Consumer preference for appearance as well as taste must be considered before any new pear cultivars are released into the market in order for the fruit to be a success. The relationship between the objective assessment of sensory attributes of pear fruit and the corresponding consumer and sensory panel rating was studied among 11 selected pear genotypes. These genotypes consisted of commercial cultivars as well as promising selections from the ARC Infruitec-Nietvoorbij pear breeding program, selected to cover the range of pear skin colour from green to full red. Pears were harvested at optimum firmness and stored at -0.5 ºC. Samples were removed after approximately four, six and ten weeks. Fruit maturity and quality parameters were measured. A trained panel assessed sensory attributes and consumer preference for appearance and overall taste was recorded.

Consumers had the highest preference for lightly coloured blush pears with a red on green or yellow colour combination. The measured chroma value had a nearly significant positive correlation with consumer preference for appearance suggesting that brighter colours are preferred over dull colours. In general, peeled samples had a higher degree of liking for taste than unpeeled, in particular for samples with astringency. The majority of consumers indicated that a soft and juicy pear with a sweet taste was their preference. Consistent with this, consumer preference for taste showed a positive correlation with juiciness and sweet taste and a negative correlation with the measurements and attributes relating to firmness. Other significant positive correlations with degree of liking of taste were overall pear flavour and melt character and sour taste and astringency both had significant negative correlations with taste. These results were consistent with previous studies performed internationally. Differences in consumer preference between genotypes were consistent over the three assessment dates indicating that the genotypic differences may override the effect of fruit maturity.

Key words: *Pyrus communis*, sensory, appearance, taste

INTRODUCTION

The external appearance of fresh fruit is an important aspect to consider when presented in the market place, as the consumer can form an expectation of what the fruit may taste like by simply viewing it (Imram, 1999). Appearance includes a number of basic sensory attributes such as colour, opacity, gloss, visual structure and visual texture (Imram, 1999).

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Perceived flavour can also be included as a sensory attribute; by viewing the product one can form an idea of what the flavour may be from previous experience and knowledge (Raats *et al*., 1995). Of all these aspects, the effect of colour is possibly the most important (Imram, 1999). South Africa is a major producer of blushed pears and these pears achieve good prices on the local and export market (Human, 2005). It is therefore important to stay ahead in the development of these selections with a high colouring potential as the competitors are realising the money involved. Apart from this, it is important to know which colour of pear is preferred by consumers and if they do in fact have preference for a blushed pear over a different colour. Kappel *et al*. (1995), for example, found that a yellow skin with slight blush was preferred. The influence of appearance on the perception of internal qualities must also be understood as external features such as skin colour and fruit size are not always good indicators of internal composition (Kingston, 1991). Visual sensory properties are of critical importance especially where the products are judged primarily through appearance properties and not packaging (Imram, 1999).

Sensory analysis of fruit quality and degree of liking usually form an integral part of many studies regarding consumer preference of appearance or taste of fruit. For descriptive sensory analysis, a number of panellists are trained to score each sample for sensory attributes, for example, texture, sweetness, acidity and overall flavour/aroma. Texture can be described by different terms but the most common are crispness, juiciness and firmness (Daillant-Spinnler *et al*., 1996). Texture is a significant feature of pear quality as well as the ripening of the fruit. As the pear ripens, a loss of firmness is observed. This softening is due to changes in the cell wall components. Texture after ripening is dependent on maturity at harvest, length and type of storage, ripening conditions and their interactions (Eccher Zerbini, 2002). Increased maturity usually occurs with the fruit firmness and titratable acidity decreasing and the total sugars and rate of starch disappearance increasing (Mann and Singh, 1985). External appearance such as skin smoothness, skin colour, and fruit size and shape descriptors are not always assessed. Acceptability of eating quality, using a nine-point hedonic scale is used by the consumers. Some studies compare the results of the instrumental data with the results of the consumer panels and focus on overall acceptability (e.g. Jaeger *et al.*, 2003; Predieri *et al*., 2002). With this, the focus is on overall acceptability. Fruit is usually given as segments for the method of presentation. Williams and Carter (1977) as well as Daillant-Spinnler *et al*. (1996) presented peeled and unpeeled segments of apples to their consumers and seemed to get similar results for both groups.

Jaeger *et al*. (2003) used a sentence completion method of gathering responses to the question “To me, the ideal pear is…”. The appearance evaluation proved that there were

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preference groupings among consumers. Some preferred big and elongated/pyriform shapes; others rejected dark green and brown fruit, while others preferred round shapes and golden colours. The colour preferences included green, yellow and golden brown. Red was not mentioned and a reason given for it was that red pears are not generally found in the market place of the consumers. However, when images of four different red skinned pears were shown to these consumers, only 15% did not show any preference. It was found overall, that appearance is the critical aspect of acceptance. Kappel *et al*. (1995) also assessed the ideal pear sensory attributes for consumer preference of new cultivars and found that the results from the trained panels were very similar to that of the consumer panels. The most acceptable skin colour seemed to be yellow while the preferred shape was elongate-concave. It was found that as the amount of red blush increased on the preferred selection, the fruit decreased in liking.

The main purpose of this study was to correlate the physical and sensory characteristics of 11 pear genotypes, selected to cover a range of skin colours, with consumer preference for appearance and eating quality. The first aim was thus to determine the preference of pear skin colour or appearance among consumers and also to determine the preference based on tasting the sample. The pears were stored for three different storage periods and the three assessment dates were approximately two weeks apart as to enable each pear cultivar to be at optimal maturity for tasting. By using peeled and unpeeled segments, the influence of the skin colour on the perception of internal qualities were analysed, and if there was in fact an influence. Questionnaires and sentence completion were used to collect descriptions of an ‘ideal’ pear in the minds of the consumers. These answers were then compared with the outcomes of the preference analyses. The second aim was to determine the drivers of liking by correlating the sensory and physical attributes of the respective genotypes with their consumer preference.

MATERIALS AND METHODS

Genotypes

Eleven pear genotypes (*Pyrus communis* L.), including five commercial cultivars were selected for this study. The pears that were selected were mainly based on external appearance. As this study partly focuses on the consumer’s preference of colour, pear genotypes of a variety of skin colours were chosen. The pears studied included two blushed cultivars; Rosemarie and Flamingo, four blushed selections; 3D-13-34, 3D-15-35, 15A-5-20 and 3D-67-5, two fully red cultivars; Red d’Anjou and Bon Rouge, a fully green cultivar;

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Packham's Triumph, and two brown russet selections; 3D-41-5 (also has a red over colour) and 3D-37-38. Photographs of these genotypes are shown in Figure 3.1.

Harvest

All selected genotypes were harvested at their optimum firmness, between 6 - 8 kg (8 mm plunger, Firmness Texture Analyser). The pears were sourced from three different areas in the Western Cape, South Africa; Elgin (latitude: 34º10'S, longitude: 19º03'E), Ceres (latitude: 33º23'S, longitude: 19º19'E) and Stellenbosch (latitude: 33º58'S, longitude: 18º50'E). All fruit was harvested within one month from 9 January 2007 to 12 February 2007. The typical harvesting period for pears in South Africa is mid-January to end March. Fruit was kept in cold storage at -0.5 °C at ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa and once all had been harvested, brought to the cold storage facilities at the Department of Horticulture at Stellenbosch University. Analyses were done on three assessment dates; 12 March, 26 March and 23 April 2007. Four days prior to the commencement of the analyses, 42 pears (3 replicates of 14 fruit) were randomly selected from each genotype and placed in a 15 °C ripening room.

Experimental design

Each pear used in this study had all the analyses performed on it, i.e., maturity indexing, descriptive sensory analysis and consumer sensory analysis. As the pears were removed from storage to be prepared for analyses, each was uniquely numbered and the colour instrumentally measured (Nippon Denshoku Model HR-3000, Tokyo, Japan). A photograph of each whole pear was taken after which they were halved into shade and sun exposed halves. The exposed halves were halved lengthways and one half peeled and the other left unpeeled. These quarters were halved again and thereby tasted by two consumers during the sensory analyses. The shaded halves were again halved lengthways into quarters. One quarter was used for the maturity indices and the other quarter for the descriptive sensory analysis by the trained panel. As the pears were numbered, a tracking system could therefore be used to match the physio-chemical measures of individual fruits with samples presented to the trained panel and consumers. As the exposed halves produced two results for each pear, they can be compared to each other for consistency.

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Descriptive sensory analysis

The sensory panel consisted of 14 assessors. The panel was trained using the consensus method as described by Lawless and Heymann (1999) and tested for consistency. A 100 mm unstructured line scale, where the left side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity, was used for each attribute. A sample from each selected pear genotype was used to train the panel for sensory attributes. The judges agreed on a consensus list of attributes for describing pear aroma, flavour and texture. The definitions for the sensory attributes analysed are similar to those used by Jaeger *et al*. (2003) and are given in Table 3.1.

The 11 pear genotype samples were analysed during nine sessions (three replications at the three time periods). The panellists were seated individually at sensory booths, which were light and temperature controlled (21 ºC). Pear samples were each coded with a three digit random code and presented on Petri dishes (Kimix, South Africa) in a complete randomised order. A sharp knife was available to the judges who were asked to peel the pears. Each sample was approximately 1.5 cm wide and was served with the peel facing the panellist. Flavour and texture attributes were assessed on the pear flesh and not the peel. Still water and unsalted biscuits (Woolworths, South Africa) were available for the judges to clean their palates between samples.

Consumer sensory analysis

Approximately 150 consumers at each assessment date were asked to complete standard questionnaires analysing six genotypes (peeled and unpeeled segments) of the 11 genotypes in the study according to overall degree of liking. A balanced incomplete block design was used. The analysis consisted of three questionnaires; Q1, Q2 and Q3. Q1 was the sensory analysis of the peeled samples, Q2 was the analysis of the unpeeled samples and Q3 was the analysis of the photographs of each pear including a number of questions relating to the consumer’s perception of the ideal pear that the consumers were asked to fill in. The samples were approximately 1.5 cm wide and the unpeeled samples were presented to the consumers with the peel facing them. Each treatment was presented in an open Petri dish with a three digit random code. The consumers were asked to only taste the flesh of the samples and not bite into the peel of the fruit. In this test, the consumer was asked to indicate which term best describes his/her attitude towards the products being tasted using the nine-point hedonic scale with the categories ranging from 9 (like extremely) to 1 (dislike extremely) with 5 being neutral (neither like nor dislike) (Lawless and Heymann, 1999). This gives an indication of

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preference as well as acceptance. Still water and unsalted biscuits were available for the consumers to cleanse their palates between samples. Photographs of the whole pears were presented on the third questionnaire and consumers were asked to analyse the pears according to degree of liking of appearance.

Physical measurements

The colour of each pear was measured using a colorimeter at the mid point between the calyx and the stem, and for pears with a red colouring, at the reddest position. The lightness, chroma and hue angle were recorded. The rest of the maturity indices were measured on only the halved green side. Flesh firmness (kg) was measured using a penetrometer (Southtrade fruit pressure tester, Model FT 327, Alphonsine, Italy) fitted with an 8 mm probe. Only one reading was taken.

Once the firmness had been measured, the pear quarters were placed in a juice extractor and the juice used to determine the total soluble solids (TSS) and the titratable acidity (TA). TSS, which represents the fruit's sugar content, was measured using a calibrated hand held refractometer (TSS 0-32%, Model N1, Atago, Tokyo, Japan). TA was determined using an automated titrator (Tritino 719S and Sample Changer 674, Metrohm Ltd., Herisau, Switzerland) by titrating 5 g of juice from each pear sample with 0.1 N NaOH to an end point pH of 8.2. The TA is expressed as percentage malic acid.

Statistical procedures

The purpose of this study was to analyse 11 pear genotypes according to physical and sensory attributes, and consumer preference over three assessment dates. At each assessment date, 42 pears were randomly selected and each fruit was physically analysed, subjected to sensory analysis and analysed by approximately 150 consumers according to the degree of liking on a 9-point hedonic ordinal scale for appearance and taste (Lawless and Heymann, 1999).

The three sets of data were subjected to an 11 x 3 factorial analysis of variance (ANOVA) in a complete randomised design using SAS statistical software (SAS, Version 9, 1999, Cary, North Carolina). Shapiro-Wilk's test was performed on the residuals to test for non-normality (Shapiro and Wilk, 1965). In the cases of significant evidence against normality, which was due to skewness, outliers were identified and removed until the residuals were symmetric or significantly normal (Glass *et al.*, 1972). Means were compared with Student's t-LSD (Least Significant Difference) at a 5% significance level. Since no

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significant interaction was found, the Cultivar x Time combination means of all the data sets was combined. XLStat software (Addinsoft, Version 2007, Paris, France) was used to perform Pearson's correlation between physical and sensory attributes and for physical and sensory attributes with consumer preference. Furthermore, a PCA (Principle Component Analysis) was also performed to identify variables that associate with certain cultivars. External preference mapping was performed by regressing the consumer data (y space) with the physical and the sensory attribute values (x space) using Partial Least Squares (PLS) modelling.

RESULTS AND DISCUSSION

The analyses were performed on three different dates over a period of two months. The overall mean values of the results for the three dates will be discussed as no significant cultivar interaction with assessment date was observed.

Colour

The colour of each pear fruit was measured halfway between the calyx and stem ends for green, yellow and brown genotypes and on the reddest position for red coloured pears at each assessment date. The lightness, chroma and hue angle were recorded and the overall mean values can be seen in Table 3.2.

The hue angle of pears ranged from 26º (red) to 103º (yellow-green). Brown pears had hue angles of 59º to 83º. 'Packham's Triumph' had the highest hue angle as it is a full green pear. '3D-41-5' and '3D-67-5' had lower values and were significantly different to 'Packham's Triumph'. These two pears had a slight red colouring over the green ground colour. '15A-5-20', 'Flamingo' and '3D-37-38' had hue values lower than the previous group and were not significantly different from each other. The former two genotypes are blush pears and the latter a brown pear. This pear may have had a slight red colouring from sun exposure. 'Rosemarie' has a slightly lower hue angle to aforementioned pears. '3D-13-34'and '3D-15-35' are red pears and not significantly different to 'Rosemarie'. 'Bon Rouge' had a lower hue angle and the lowest and darkest red colour pear was 'Red d'Anjou' with a hue angle of 25.9.

The chroma values range between 50 and 19. A lower value for chroma indicates a dull or paler colour and a higher value indicates a brighter colour. The genotype with

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significantly the highest chroma value is '15A-5-20'. 'Packham's Triumph' is slightly lower than this and, 'Flamingo', 'Rosemarie' and '3D-67-5' have lower chroma values than 'Packham's Triumph'. These pears are brightly coloured. '3D-13-34' has a slightly duller complexion with a chroma value under 37. '3D-15-35', '3D-41-5' and '3D-37-38' were lower than this. 'Bon Rouge' has the second lowest chroma value and 'Red d'Anjou' the lowest with a value of less than 20. This pear would seem to have the dullest complexion.

The lightness of the pear refers to how lightly or darkly coloured skin colour is. The lightness ranged from 64, which was the genotype '15A-5-20', to 'Red d'Anjou' with a value of 34.2. 'Packham's Triumph' had the second highest value but was not significantly different to '15A-5-20', and '3D-67-5' was not significantly different to 'Packham's Triumph'. The blush pears, 'Flamingo and 'Rosemarie', had a lower value and '3D-41-5' even lower. '3D-37-38' was lower but not significantly different to the latter genotype and '3D-13-34' not significantly different to '3D-37-38'. '3D-15-35' was not significantly different to '3D-13-34' and 'Bon Rouge' again had the second lowest value overall with 38.1. 'Red d' Anjou' was the darkest in colour with a lightness value of 34.

Preference of appearance

Over 450 consumers took part in this part of the research over the three assessment dates. The acceptability of appearance was measured on a vertical scale from one (*dislike extremely*) to nine (*like extremely*) with 5 being neutral (*neither like nor dislike*). The overall mean values for the total consumer's degree of liking of the appearance for each genotype are shown in Table 3.2.

The genotypes that received overall means of above 6.0 can be seen as favourable according to their appearance. 'Flamingo' and 'Rosemarie' received the highest preference with values of 7.3 and 7.2, respectively. These are both in the category of 'like moderately'. 'Packham's Triumph', '3D-13-34' and '15A-5-20' obtained values between 6.4 and 6.0 which is therefore still a positive liking in the category 'like slightly'. A slightly lower preference was given to 'Bon Rouge' but not significantly different to '15A-5-20'. This genotype was scored as having a neutral liking. The same goes for '3D-15-35' (not significantly different to '15A-5-20') and '3D-67-5' which do not differ significantly from each other. The remaining three genotypes, '3D-41-5', 'Red d'Anjou' and '3D-37-38' have the lowest degree of liking of appearance. They all received a negative liking below 5.0 and do not differ significantly from each other.

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Of the three colour measurements, chroma had the strongest correlation, albeit not significant ($r=0.567$; $p=0.069$), with the degree of liking of appearance. The scatterplot of this relationship is shown in Figure 3.2. As chroma is the most important colour measurement, it suggests that the brightness of the peel colour may influence the consumer's preference of appearance. It has also been found with other studies that brighter coloured fruit is preferred by consumers over fruit that has a duller complexion (Baarschers, 1996; Sanderson, 2007). 'Rosemarie' and 'Flamingo', the pears with the highest preference, are both blushed cultivars with a typical pear shape. These two genotypes have similar lightness and chroma values and the hue of 'Flamingo' is only slightly higher than that of 'Rosemarie'. One of the least liked pears, 'Red d'Anjou', had by far the lowest values for chroma and lightness; this is a very dark and dull pear, with an almost round shape. The other two genotypes with the lowest degree of liking, '3D-41-5' and '3D-37-38', had similar low chroma and lightness values but are both selections with a pear shape although both had varying amounts of russet covering. '3D-37-38' also had a slight green colouring and '3D-41-5' had green and red markings. The brown colour due to russeting was therefore unpopular with the consumers. Turner *et al*. (2005) also found that consumers chose yellow or blush colours over a brown pear. The round shape of 'Red d'Anjou' was also not favourable. The genotypes '3D-13-34' and '3D-15-35' had similar hue values as well as similar lightness and chroma values to 'Flamingo' and 'Rosemarie'. Although '3D-13-34' received a high degree of liking for appearance, '3D-15-35' did not. This genotype has a small, round shape. Here again it is confirmed that the shape of the pear plays an important role in the influence of preference. Turner *et al*. (2005) found that consumers preferred the typical pear shape of 'Williams Bon Chrétien'. 'Packham's Triumph', the only genotype in this selection with a light green peel colouring, received a high score for consumer preference, probably relating to its high chroma value. This is also true for '15A-5-20' which also has a high chroma value (similar chroma and lightness to 'Packham's Triumph'). It appears that a blush colouring is preferred by the consumers as the rest of the blushed genotypes (3D-13-34, 3D-15-35, 15A-5-20) received a good degree of liking (above 5.0). The green of the 'Packham's Triumph' was also preferred and received a positive degree of liking as also found by Turner *et al*. (2005). It seems that the optimum lightness value should be between 50 and 64, the chroma value between 39 and 50 and the hue angle between 45º and 63º. If a pear has these features it will ensure that the skin has a light and bright character with a bright red or pink blush (Sugar and Dussi, 1998). The selections did not compare too badly against the established cultivars. Both '3D-13-34' and '15A-5-20' received mean values of over 6.0 for degree of liking of appearance.

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Sensory characteristics

The trained panel analysed different texture characteristics (Table 3.1) on the 11 pear genotypes. The mean values for each characteristic from the three replications at each assessment date are shown in Table 3.3. Important attributes for pears, as stated by the consumers, are sweetness, juiciness, pear flavour and softness and Predieri *et al*. (2005) found that sweetness and pear aroma correlated highly with the consumer's preference. The sensory attributes concerning the firmness are hardness and crunchiness and they have a very strong positive correlation ($r=0.995$; $p<0.0001$) with each other. For this reason, hardness was chosen to represent the texture of softness or hardness in the discussion. Based on the answers provided, genotypes with high values for sweetness, juiciness and pear flavour and a low value for hardness would be expected to receive the highest preference by the consumers.

'3D-15-35', 'Bon Rouge', 'Flamingo' and 'Rosemarie' had significantly highest perceived sweetness and '3D-67-5' the lowest. '3D-37-38', 'Packham's Triumph' and 'Red d'Anjou' received slightly higher values but were not significantly different from each other. The remaining genotypes had a moderate sweet taste but '15A-5-20' was not significantly different to '3D-37-38', and '3D-13-34' and '3D-41-5' received higher values than these but lower than the top group.

Pear flavour showed similar patterns. The highest values were the same genotypes as that for sweet taste and the '3D-67-5' also had significantly the lowest value. The middle group does in fact differ. '3D-13-34' and '15A-5-20' have slightly lower values than the top group and '3D-41-5' less than these. '3D-37-38', 'Packham's Triumph' and 'Red d'Anjou' are not significantly different from each other and form the second lowest group.

'Flamingo' and 'Rosemarie' had the highest perceived juiciness and 'Bon Rouge' did not differ significantly from 'Rosemarie'. 'Packham's Triumph' has a slightly lower juiciness with a value of 32.3. '3D-13-34', '3D-41-5', '3D-15-35', '3D-37-38', '3D-67-5' and 'Red d'Anjou' all have a similar perceived juiciness with values between 20 and 30. '15A-5-20' had significantly the lowest juiciness, below 17.

'15A-5-20' also had significantly the lowest perceived hardness. '3D-67-5' had the hardest texture overall. 'Packham's Triumph' and 'Red d'Anjou' were perceived as being slightly softer and '3D-37-38' and '3D-41-5' even softer than these. The group of 'Rosemarie', 'Flamingo', 'Bon Rouge' and '3D-15-35' did not differ from each other and had

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the second lowest hardness. These genotypes as well as '3D-13-34' would all be viewed as pears with a soft texture.

Melt character is also a positive attribute for pears (Eccher Zerbini, 2002). 'Flamingo' had significantly the highest melt character. '3D-15-35', 'Bon Rouge' and '15A-5-20' did not significantly differ from each other and were the next highest perceived meltiness. All these together with 'Rosemarie', which did not differ from '15A-5-20' and 'Bon Rouge', were all genotypes with a relatively high melt character and would increase the degree of liking for consumers. The remaining genotypes all have values lower than 12.1 ('3D-13-34') and '3D-41-5' and '3D-37-38', being below 10. '3D-67-5' received the lowest measurement but 'Red d'Anjou' and 'Packham's Triumph' were not significantly higher.

Attributes such as astringency, a high sour taste and mealiness are generally thought to be negative characteristics relating to pears (Boylson *et al*., 1994), as well as grittiness or a grainy texture for some consumers (Jaeger *et al*. 2003). According to Table 3.3, sample '3D-37-38' is the only genotype (apart from '3D-67-5' that has a relatively high value) with a considerably high astringency value. The remaining genotypes are all below 8.5. '3D-67-5' had significantly the highest perceived sour taste with 39.4 followed by '3D-37-38' with 25.4. The remaining genotypes were all below 20. These would therefore not be seen as having a substantial sourness. '3D-41-5', '3D-15-35' and '3D-13-34' had the lowest sour taste overall (below 6). '15A-5-20' was significantly the mealiest genotype. This was the by far the highest mealiness at 52.5 as the next genotype, '3D-15-35' has a mealiness of only 16.8. The majority therefore had a reasonably low mealiness and did not differ greatly between each other. The highest grittiness was found in 'Flamingo' which still had a high degree of liking with the consumers. '3D-41-5', which did not differ significantly from 'Flamingo', also had a relatively high grittiness followed by 'Red d'Anjou' and '15A-5-20'. '3D-37-38', 'Bon Rouge', '3D-15-35', '3D-13-34' and '3D-67-5' all had similar values but less than the previous group. 'Packham's Triumph' and 'Rosemarie' had the lowest perceived grittiness.

The genotypes with high values for sweetness, juiciness and pear flavour and a low value for hardness would be expected to receive the highest preference by the consumers as this is the attributes stated to be important in Q3. 'Bon Rouge', '3D-15-35', 'Flamingo' and 'Rosemarie' had significantly highest perceived sweetness and pear flavour. 'Flamingo' and 'Rosemarie' had the highest perceived juiciness. The genotype with significantly the lowest perceived hardness was '15A-5-20' followed by '3D-15-35', 'Bon Rouge', 'Flamingo' and 'Rosemarie'. Even though '15A-5-20' has a low firmness which is a positive attribute, its mealiness would influence the consumers negatively and the pear would be seen as being

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over-ripe. The latter three genotypes would therefore be expected to have the highest degree of liking for taste.

Physical measurements

The instrumental measurements taken were firmness, TSS and TA. The mean values of these measurements together with the TSS/TA ratio are shown in Table 3.4. As sweetness and low firmness are important characteristics of pears, the genotypes with the highest and lowest measured firmness and TSS were determined. These answers did not agree with the perceived results.

The firmest genotypes measured were '3D-41-5' and 'Packham's Triumph' followed by '3D-13-34' (not differing significantly from 'Packham's Triumph'), '3D-67-5' and '3D-37-38'. 'Red d'Anjou' did not differ significantly from the latter two genotypes. The genotypes with the lowest firmness were 'Flamingo' and '15A-5-20', and the group with a slightly higher firmness than these were 'Bon Rouge', '3D-15-35' and 'Rosemarie'.

There was not much variation among the TSS values. '3D-37-38' had a significantly higher TSS, followed by '3D-15-35', but the remaining genotypes ranged between 13.9 ('3D-13-34') and 12.4 ºBrix ('3D-67-5'). '3D-37-38' had a low sweet taste perception which could be due to masking by the high astringency (Table 3.3). Standard measurements such as TSS have shown to have a poor correlation with the sensory perception in apples (Hampson *et al*., 2000; Watada *et al*., 1984) and also in pears (Predieri *et al*., 2005).

The TA value and sour taste perceived had a better agreement as '3D-67-5' had of the highest TA and sour taste measurements and the lowest was '3D-13-34'. Although, '3D-37-38' had a slightly higher TA than '3D-67-5' they did not differ significantly. The remaining genotypes range between 0.42% ('Bon Rouge') and 0.26% ('Packham's Triumph').

The TSS/TA ratio explains the sweet and sour balance in the pears. A higher ratio shows that the pears are predominately sweet and a low ratio would mean a sour pear. A relatively high ratio, between 40 and 60 is required as it will have the right balance between a sweet and sour taste (Chen *et al*., 2007), but if the ratio is too high such as in the case of '3D-13-34' (over 70), the sweet taste would be too high and overpower any sourness. 'Flamingo', 'Rosemarie' and '3D-15-35', which were of the most preferred genotypes (Table 3.5), have ratios between 43 and 57. These can be seen as moderate ratios. '3D-41-5' and 'Packham's Triumph' also fall into this range but other characteristics caused that these genotypes did not

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receive a higher preference. 'Red d'Anjou', '3D-37-38' and '3D-67-5' had low ratios between 25 and 37 and were of the least preferred genotypes. 'Bon Rouge' is also rated as one of the most preferred genotype by the consumers (Table 3.5) yet it has a low TSS/TA ratio. The firmness of this genotype seems to be an optimum value for the preferred texture and moderate sugar content and acidity was measured, which may have resulted in a low ratio but is still satisfactory for consumers' taste.

Preference of taste

Preference of taste includes the flavour or aroma and the texture of the fruit. The overall taste of the peeled as well as the unpeeled segments was analysed by the consumers. The degree of liking is shown in Table 3.5 for the peeled and unpeeled samples. The results for the peeled and unpeeled samples follow similar patterns and there is a strong positive correlation ($r=0.995$; $p<0.0001$) between these two factors and Figure 3.3 shows a scatter plot of this.

The peeled samples of 'Flamingo', 'Bon Rouge' and 'Rosemarie', were significantly more preferred compared to other genotypes except for '3D-15-35' which also received a high degree of liking for taste. '3D-13-34' obtained 6.0 as a peeled sample, significantly less than 'Rosemarie', 'Flamingo' and 'Bon Rouge' but is still seen as a positive degree of liking. '3D-37-38' was significantly the least favoured pear, without a peel, receiving less than 3.0 overall. '3D-67-5' was the second least preferred pear and '15A-5-20' was also awarded a negative degree of liking (below 5.0). 'Red d'Anjou' received 5.1 but was not significantly different to '15A-5-20'. 'Packham's Triumph' and '3D-41-5' received a neutral degree of liking (between 5.5 and 6.0).

As for the unpeeled samples, 'Flamingo' received the highest degree of liking compared to other genotypes except for 'Bon Rouge' and 'Rosemarie'. 3D-15-35' did not differ significantly from these two genotypes and received a positive liking, above 6.0. '3D-13-34', 'Packham's Triumph' and '3D-41-5' had a neutral degree of liking; neither like nor dislike. The remaining four genotypes, 'Red d'Anjou', '15A-5-20', '3D-67-5' and '3D-37-38' received the lowest degree of liking, all below 4.0. These all differed significantly from each other and '3D-37-38' was therefore significantly the genotype with the lowest preference.

As mentioned, the general pattern is that the values for the unpeeled samples were either identical or slightly less than the peeled samples. No genotype had a higher degree of liking for the unpeeled sample than the peeled sample. Only '3D-41-5', '3D-37-38' and 'Red

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d'Anjou' had a significant difference between peeled and unpeeled samples, most likely causing the overall significant difference. The greatest of these was '3D-37-38', but both values had significantly the least degree of liking (below 2.9). The consumers did eat the peel together with the flesh in the unpeeled samples; the peel therefore did play a role regarding certain sensory attributes. The overall pear flavour was positively correlated with the peeled (r=0.753; p=0.007) and unpeeled segments (r=0.762; p=0.006). Pear flavour is a favourable attribute and the peel does not play a role in affecting this. The same applies to sweet taste and the peeled (r=0.792; p=0.004) and unpeeled pears (r=0.791; p=0.004). There is a high negative correlation between astringency and the unpeeled segment (r=-0.832; p=0.001) and astringency and the peeled segment (r=-0.842; p=0.001). The negative correlation is obvious due to consumers generally disliking an astringent taste but the compounds responsible for astringency lie near the peel (Amos, 2007) which would be expected to cause more dislike.

The results of the consumer's preference for appearance and for taste of the unpeeled genotypes showed a slight positive correlation (r=0.655; p=0.029), yet Liu *et al*. (2005) did not find a correlation between fruit appearance and eating quality. This is not to say that the peel colour had an influence on the taste of the pear fruit as the segment given to the consumers to taste was not more than 1.5 cm thick. The positive correlation could be a coincidence or the consumer could be familiar to a certain type of pear with a specific colour and therefore make assumptions based on past experiences (Jaeger *et al*., 2003).

Overall, the consumers enjoyed the samples with the soft and juicy texture such as 'Flamingo', 'Rosemarie' and 'Bon Rouge'. The two selections '3D-13-34' and '3D-15-35' compared well to the established cultivars in terms of general taste (above 5.8), whereas, '3D-37-38' and '3D-67-5' obtained less positive results for general taste (both disliked very much). The remaining two selections received average values by the consumers.

At the end of the third questionnaire given to the consumers, they were asked three additional questions, namely what colour pear do they prefer, which cultivar they normally purchase and which taste and texture attributes or visual features do they enjoy in a pear. A large number of the consumers (40%) did not complete these questions but from those that did, the majority answered red and green for pear skin colour (25%). The second most answered colour was a red and yellow combination (17%) followed by a green peel colour (16%). When asked which cultivars they preferred, there were very few valid answers as some gave the colour of the fruit or the store at which they purchase the fruit as an answer. This shows that consumers do not know pear cultivar names and are not aware of available cultivars in South Africa. The few cultivar names that were correctly mentioned showed that

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the blushed cultivar, Forelle, was the most enjoyed by 11% of the consumers. Cultivars such as Packham's Triumph (4%), Bon Chrétien (4%) and Rosemarie (3%) were also mentioned. Sweet taste was by far the ideal taste preferred by consumers with 48% of the answers. A small percentage (11%) indicated that a strong pear flavour was important to them and 8% liked a sweet and sour balance. A small amount listed a sour taste (4%), a fresh taste (3%) and no astringency (2.5%). One consumer indicated that a bitter taste was preferred. There were many attributes described for texture. The most frequently mentioned attributes were juicy (19%), soft (18.5%) and not mealy (15%). This corresponds to the most important sensory traits in pears that were found by Kappel *et al*. (1995) and Predieri *et al*. (2002). Other attributes mentioned were a white flesh, a light or creamy flesh, the peel must not be too hard, not too watery and not overripe. The answers given for other visual characteristics that influence consumers when purchasing pears are shape; pear shape, curvy shape, large and regular form – not like an apple. Jaeger *et al*. (2003) also found that consumers preferred an elongated or a pyriform (typical pear) shape when asked to explain their ideal pear.

These answers regarding the 'ideal pear' for consumers showed a similar outcome to that of the analysis of the photographs depicting the appearance and colour of the respective samples. As the most widely known pear cultivar of this group of consumers is 'Forelle', this agrees with the results from the preference of appearance for 'Rosemarie' and 'Flamingo' as these are both blushed pears. The most liked attributes are sweet and juicy which agrees with the sweet taste and juicy texture of 'Rosemarie', 'Flamingo' and 'Bon Rouge'. The results from the study done by Jaeger *et al*. (2003) found that the descriptions, given by the consumers, of their ideal pear coincided with the results from the study that Gamble *et al*. (2006) performed on images of pears with a similar target market.

Drivers of degree of liking

Preference mapping uses statistics to explain differences in consumer liking for a product, for example, what one consumer likes; another may dislike (Harker *et al*., 2008). A partial least squares (PLS) was performed on all the collected data as overall mean values and can be seen in Figure 3.4. The maturity indicators (firmness, hardness, crispness and crunchiness) were included in Figure 3.4 but not in Figure 3.5 to assess the drivers of liking independent of maturity.

The observations that lie close to each other denote a positive correlation and if they are lying at opposite ends of the map, a negative correlation is found. In Figure 3.4 'PrefPeeled' and 'PrefUnpeeled' lie next to each other which prove that the results follow a

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similar pattern and no large differences are evident. Juiciness has the highest association with the consumer's preference for taste which means that juiciness is a strong driver of preference (r=0.731; p=0.015). The correlations with the sensory attributes are shown with the preference for taste of unpeeled samples. Other strong correlations include sweetness (r=0.791; p=0.004), pear flavour (r=0.762; p=0.006) and melt character (r=0.630; p=0.038). Even though these lie slightly further away, they do have a strong influence in the consumer's degree of liking. The preference of the appearance has a positive correlation with the preference for taste of the peeled samples (r=0.620; p=0.042) and of the unpeeled samples (r=0.655; p=0.029), but colour measurements do not seem to play a major role in influencing preference for appearance. This is possibly attributable to a non-linear relationship between colour and preference with blushed fruit with intermediate hue angles preferred over brown fruit (also with intermediate hue angles), green fruit (high hue angles) and full red fruit (low hue angles). As stated previously, only the chroma measurement had a positive correlation (r=0.567; p=0.069) with preference for appearance (Figure 3.3). The TSS and TA measurements lie opposite to the consumer's preference for taste values but the TSS/TA ratio is close by. The consumers could prefer a balance of sweet and sour taste instead of a primarily sweet taste or sour taste (Boylson *et al*., 1994) as seen by the TSS/TA ratios of 'Rosemarie', 'Flamingo' and '3D-15-35' which are all relatively high ratios (but not too high such in the case of '3D-13-34') and were the genotypes that were most preferred. '3D-37-38' and '3D-67-5' have the lowest ratios and were the least preferred for taste by the consumers. Sour taste (r=-0.725; p=0.012), and astringency (r=-0.842; p=0.001) have significantly negative correlations with the preference of taste. The sensory attributes mealiness and grittiness also negatively influence taste and have a negative association with preference of taste but do not correlate significantly.

The group of genotypes, 'Rosemarie', 'Flamingo', '3D-13-34' and 'Bon Rouge' lie closest to 'PrefPeeled' and 'PrefUnpeeled'. These were overall the most favoured genotypes for the consumers. The maturity indicators (firmness, hardness and crunchiness) are situated on the left hand side of Figure 3.4, opposite to the consumer's results. This indicates a strong negative correlation and confirms that the consumer prefers a less firm pear or a pear that is at optimum maturity. It is therefore important that when presenting a pear to a consumer, the ripening conditions must be correct in order to produce optimal eating quality (Vaysse *et al*., 2005). If the pear is too hard it could be that it is still underripe. Genotypes 'Packham's Triumph' and '3D-67-5' lie closest to these maturity indicators as they were measured to have the highest firmness.

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By removing the maturity indicators in the analysis a different result is found. This is seen in Figure 3.5. On removal of firmness, hardness, crispness and crunchiness, the main influencers appear to be sweet taste, pear flavour, melt character, TSS/TA ratio and to a lesser extent, juiciness. The correlation between the preference of appearance and taste is also not as strong and even less so for the colour measurements. The same genotypes lie closest to the 'PrefPeeled' and 'PrefUnpeeled' and the same attributes and genotypes lie on the opposite side of the graph (for example, astringency, sour taste, TA, TSS and the genotypes '3D-37-38' and '3D-67-5'). The maturity indicators seem to have a negative effect on preference as the sensory attributes move closer to preference of taste when they are removed.

The measurement for TSS lies opposite to the preference for peeled and unpeeled samples in both Figure 3.4 and 3.5 and TSS does not lie near the attribute of sweet taste. The reasoning for this could be genotype '3D-37-38'. The latter sample was a very astringent sample with by far the highest TSS and TA concentration. Astringency, TA, TSS and '3D-37-38' all lie together in Figure 3.4 and Figure 3.5. The astringency masked the sweetness of this pear and thereby influenced the outcomes of the study. When this genotype is removed (Figure 3.6), the TSS measurement moves closer to the preference for taste. The physical appearance of '3D-37-38' was unappealing and received the lowest degree of liking for appearance as well as receiving by far the lowest values for taste. This could explain why the correlation between appearance and taste is initially present (Figure 3.4) and when this sample is removed, the correlation lessens as indicated in Figure 3.6. The second least liked pear is '3D-67-5'. This sample had the second highest TA value and the second lowest degree of liking for appearance as well as the highest values for hardness and crunchiness. When '3D-37-38' is excluded, there is a sub-group lying directly opposite the group containing the preference for taste. This group includes '3D-67-5' as well as the attributes sour taste, crunchiness, astringency, hardness and the measurements of firmness and TA are situated close by. These are negatively correlated with the preference for taste; i.e., the consumers did not accept samples with a high sourness (Eccher Zerbini, 2002), firmness (Vangdal, 1982) or astringency (Mielke *et al*., 2005).

CONCLUSION

The three storage times did not seem to play a significant role as there was no obvious increase in maturity of the pears and the differences in consumer preference between genotypes were consistent over the three assessment dates. It is likely that genotypes that received a low preference for taste were not eating ripe and may attain a much higher score

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when at optimum maturity. Hence, it is not to say that these genotypes are inherently worse than genotypes that were scored higher.

The measured chroma values and the values given for the appearance of the pear by the consumers had nearly significant positive correlation (r=0.567, p=0.069). Generally, the higher the chroma value measured, the higher the preference was for the consumers. 'Red d'Anjou', with the lowest chroma, was given the lowest values by the consumers for appearance whereas 'Rosemarie' and '15A-5-20' measured the highest chroma value and also rated highest with the consumers. The lowest scores were for russetted and dark red pears as well as pears with a round shape.

The overall preference for consumers appears to be a sweet tasting pear with a strong flavour and a soft, juicy, melty but not mealy texture. The pears should also not be sour or astringent. The skin colour must have a light green or yellow background with a bright red or pink blush. Overall the selections compared well with the established cultivars. '3D-13-34' and '3D-15-35' did especially well in both the appearance and taste preferences. '15A-5-20' received very high values for appearance but not for taste. This is because at the time of the assessment dates, these pears were already overripe and most of them could not be used in the analyses or the high amount of mealiness caused a negative response from the consumers.

Further research on this subject should include a study based on the same structure as this study but using more established cultivars and having the emphasis of the project more focused on taste. Established cultivars such as Bon Chrétien can be used as a reference sample as it is a well recognized pear with popular sensory attributes. The comparison of any included selections will be more substantiated and the preference of taste and appearance can be accurately determined.

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Table 3.1 Definition of sensory attributes used for the sensory analysis of pear fruit. Source: Jaeger *et al*., 2003.

Attribute	**Definition**	**Scale**
Overall pear flavour	Aromatics of typical pear	0 = None 100 = Very strong pear flavour
Sweet taste	Basic taste on tongue caused by characteristic sugars	0 = None 100 = Prominent sweet taste
Sour taste	Basic taste on tongue caused by characteristic acids	0 = None 100 = Prominent sour taste
Astringency	Sensation associated with drying of the mouth	0 = None 100 = Prominent astringency
Crunchiness	Noise generated when chewing with molars	0 = None 100 = Prominent crunchiness
Hardness	Force required to compress sample with molars	0 = None 100 = Very hard
Melt character	Melting of flesh in the mouth	0 = None 100 = Prominent meltiness
Juiciness	Amount of juice released by sample during chewing	0 = None 100 = Very juicy
Mealiness	Over-mature texture recognised by a soft, dry pulp	0 = None 100 = Prominent mealiness
Grittiness	Presence of small hard particles in the flesh experienced between front teeth	0 = None 100 = Prominent grittiness

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Table 3.2 Degree of liking of appearance on nine point hedonic scale for pear genotypes for total group and means of colour measurements of lightness, chroma and hue angle. Means separated by LSD (5%).

Genotype	Colour	Preference of appearance	Lightness (L*)	Chroma (C*)	Hue (h°)
Packham's Triumph	Green	6.4 b	61.9 ab	42.8 b	103.2 a
3D-41-5	Green & red	4.7 f	47.9 d	32.8 e	82.3 b
3D-67-5	Green & red	5.3 e	60.0 b	38.7 c	81.4 b
15A-5-20	Blush	6.0 bc	63.9 a	49.3 a	62.5 c
3D-37-38	Brown	4.6 f	46.4 de	33.1 e	59.6 c
Flamingo	Blush	7.3 a	51.6 c	39.6 c	57.7 c
Rosemarie	Blush	7.2 a	50.3 c	39.4 c	45.3 d
3D-13-34	Scarlet	6.3 b	45.6 ef	36.4 d	42.9 d
3D-15-35	Red	5.6 de	43.4 f	33.7 e	40.7 d
Bon Rouge	Red	5.8 cd	38.1 g	27.8 f	35.2 e
Red d'Anjou	Purple	4.7 f	34.2 h	19.7 g	25.9 f
LSD (p =0.05)		0.37	2.21	2.23	5.36
P-value		<0.0010	<0.0001	<0.0001	<0.0001

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Table 3.3 Overall means of sensory characteristics measured on a 100 mm unstructured line scale during descriptive sensory analysis. Means separated by LSD (5%).

Genotype	Pear flavour	Sour taste	Sweet taste	Astringency	Hardness	Melt character	Juiciness	Mealiness	Grittiness
Packham's Triumph	16.3 d	11.3 de	20.3 e	1.0 e	61.7 b	2.3 g	32.3 c	1.6 e	12.0 e
3D- 41-5	26.1 c	5.8 f	30.1 c	4.9 d	39.9 d	8.6 de	28.4 cde	3.9 e	25.1 ab
3D-67-5	6.5 e	39.4 a	7.9 f	19.6 b	65.9 a	0.8 g	24.3 ef	2.1 e	17.8 d
15A-5-20	37.3 b	9.6 e	25.6 d	3.1 de	7.3 g	25.6 bc	16.6 g	52.5 a	24.1 bc
3D-37-38	18.8 d	25.4 b	21.9 de	51.6 a	40.8 d	6.4 ef	25.3 def	7.7 d	21.1 cd
Flamingo	49.3 a	12.8 d	41.3 a	1.3 e	14.2 f	32.1 a	42.3 a	13.3 c	28.0 a
Rosemarie	49.0 a	12.4 de	40.8 a	6.1 c	15.2 f	24.1 c	39.4 ab	7.8 d	11.2 e
3D-13-34	41.4 b	3.4 f	36.3 b	1.2 e	28.7 e	12.1 d	29.2 cd	4.6 de	17.8 d
3D-15-35	49.3 a	5.6 f	43.8 a	0.6 e	11.8 f	27.9 b	28.1 de	16.8 b	18.6 d
Bon Rouge	51.6 a	10.8 de	41.0 a	1.0 e	14.0 f	26.9 bc	38.2 b	12.2 c	19.6 d
Red 'D Anjou	15.4 d	18.1 c	17.5 e	8.5 c	53.6 c	2.8 fg	23.7 f	3.7 e	23.4 bc
LSD (p=0.05)	4.90	3.16	4.48	3.13	3.89	3.63	4.14	3.41	3.53
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Table 3.4 Means of measured maturity indexes firmness, total soluble solids and titratable acidity and calculated ratio of total soluble solids and titratable acidity. Means separated by LSD (5%).

Genotype	Firmness (kg)	TSS (ºBrix)	TA (% malic acid)	TSS/TA
Packham's Triumph	6.8 ab	12.6 d	0.26 d	50.0 cd
3D- 41-5	7.1 a	13.7 c	0.27 d	52.9 bc
3D-67-5	6.1 cd	12.4 d	0.55 a	25.9 h
15A-5-20	3.2 g	12.9 d	0.28 d	47.1 cde
3D-37-38	5.6 cd	18.4 a	0.58 a	32.4 gh
Flamingo	3.7 fg	12.6 d	0.30 d	44.0 de
Rosemarie	4.1 ef	12.5 d	0.30 d	42.6 ef
3D-13-34	6.2 bc	13.9 c	0.20 e	73.7 a
3D-15-35	4.2 ef	16.6 b	0.30 d	57.0 b
Bon Rouge	4.4 e	13.8 c	0.42 b	34.9 g
Red 'D Anjou	5.5 d	13.5 c	0.37 c	36.6 fg
LSD (p=0.05)	0.63	0.54	0.043	6.83
P-value	<0.0001	<0.0001	<0.0001	<0.0001

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Table 3.5 Overall degree of liking of taste for the total group of the peeled and unpeeled genotypes as well as probability values of the difference between each genotype. Means separated by LSD (5%).

Genotype	Colour	Peeled (N =431)	Unpeeled (N=431)	P-value
Packham's Triumph	Green	5.7 d	5.4 de	0.1755
3D- 41-5	Green & red	5.6 d	5.2 ef	0.0278
3D-67-5	Green & red	3.7 f	3.5 h	0.5265
15A-5-20	Blush	4.6 e	4.2 g	0.0922
3D-37-38	Brown	2.9 g	2.3 i	0.0007
Flamingo	Blush	6.7 a	6.7 a	0.8861
Rosemarie	Blush	6.3 a	6.3 abc	0.7256
3D-13-34	Scarlet	6.0 bcd	5.8 cd	0.1586
3D-15-35	Red	6.2 abc	6.1 bc	0.7411
Bon Rouge	Red	6.6 a	6.5 ab	0.5847
Red 'D Anjou	Purple	5.1 e	4.7 f	0.0397
LSD (p=0.05)		0.53	0.51	
P-value		<0.0001	<0.0001	

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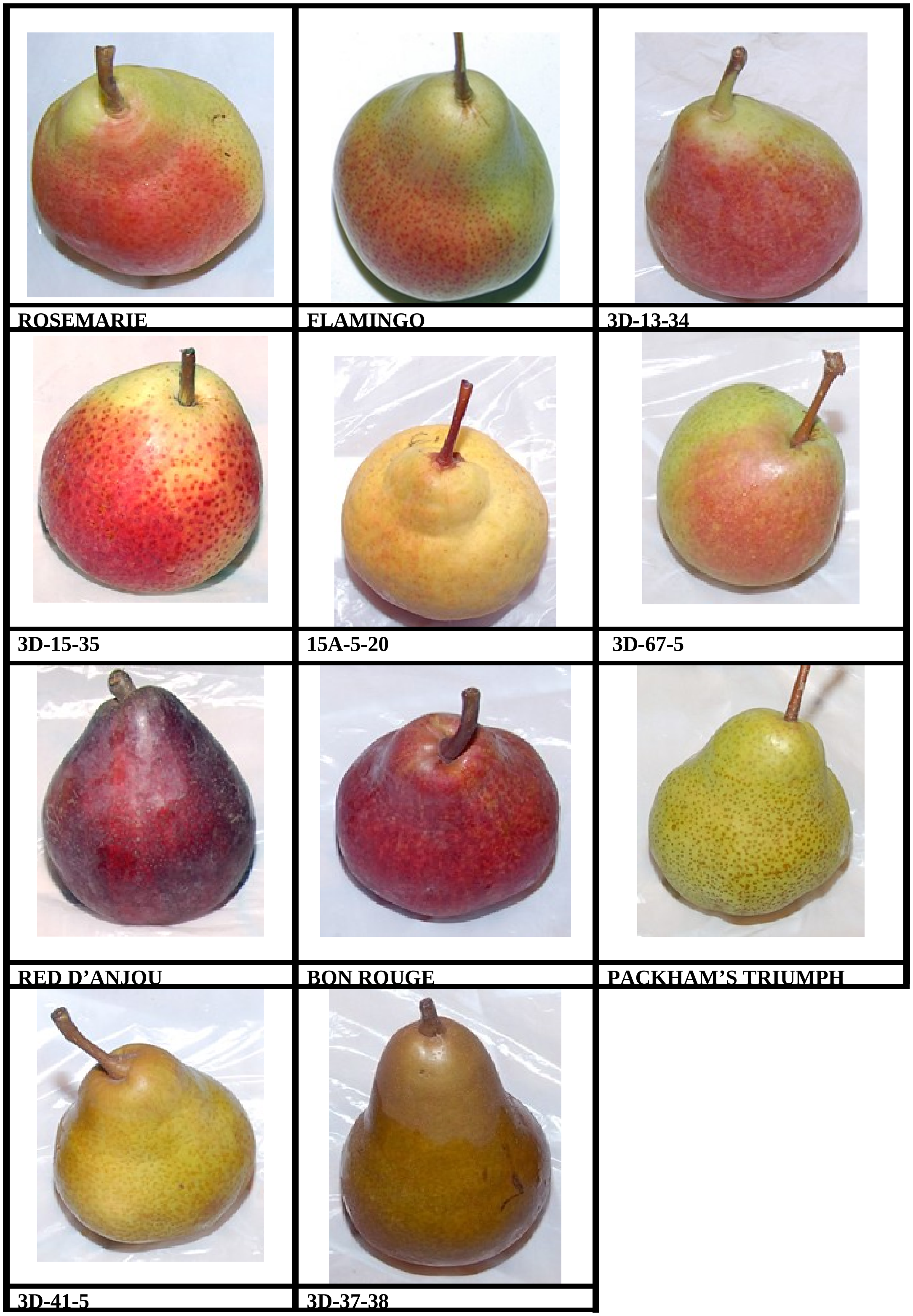

Figure 3.1 Photographs of a representative of each pear genotype used in the study taken after a minimum storage period of six weeks.

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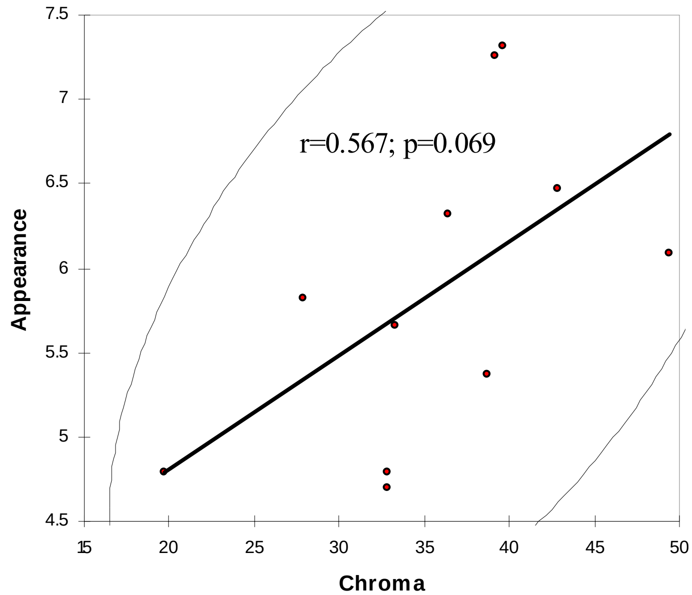

Figure 3.2 Scatter graph of overall preference for appearance against the measured chroma values of each genotype. The values for appearance were: 1 (dislike extremely); 2 (dislike very much); 3 (dislike moderately); 4 (dislike slightly); 5 (neither like nor dislike); 6 (like slightly); 7 (like moderately); 8 (dislike very much); 9 (dislike extremely). The values for preference were: 1 (dislike extremely); 2 (dislike very much); 3 (dislike moderately); 4 (dislike slightly); 5 (neither like nor dislike); 6 (like slightly); 7 (like moderately); 8 (dislike very much); 9 (dislike extremely).

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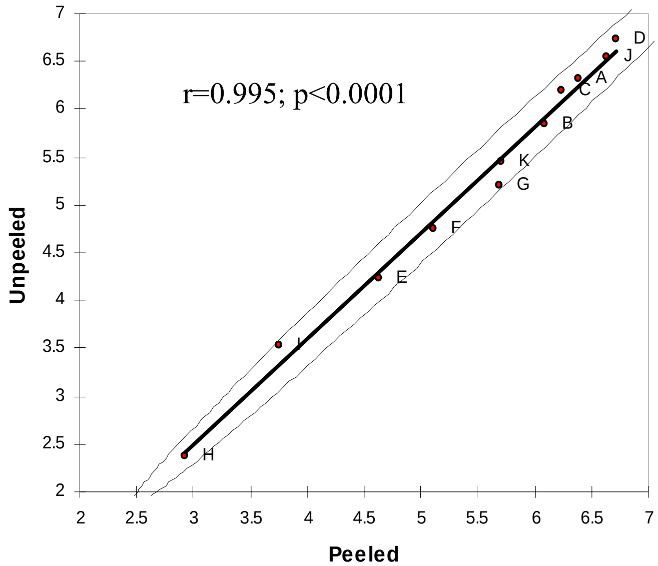

Figure 3.3 Scatter plot of overall preference of taste for the peeled samples against unpeeled samples from the total group of consumers (N=431). The pear genotypes were: Rosemarie (A); 3D-13-34 (B); 3D-15-35 (C); Flamingo (D); 15A-5-20 (E); Red d'Anjou (F); 3D-41-5 (G); 3D-37-38 (H); 3D-67-5 (I); Bon Rouge (J); and Packham's Triumph (K). The values for preference were: 1 (dislike extremely); 2 (dislike very much); 3 (dislike moderately); 4 (dislike slightly); 5 (neither like nor dislike); 6 (like slightly); 7 (like moderately); 8 (dislike very much); 9 (dislike extremely).

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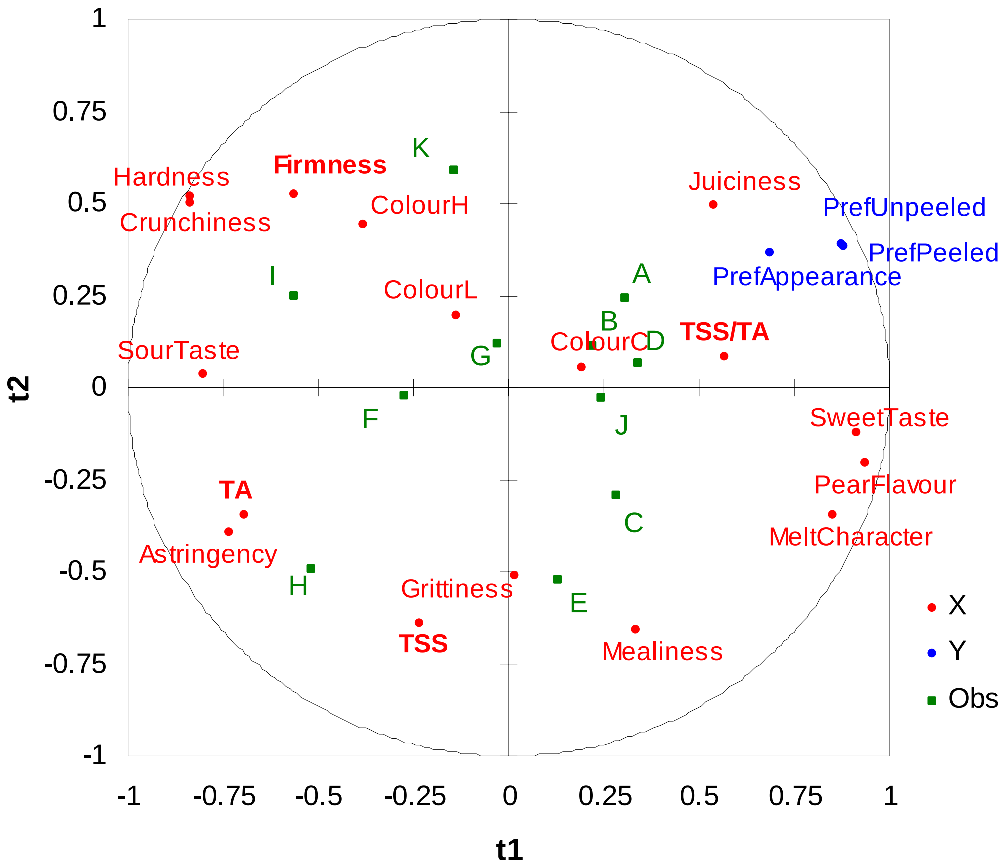

Figure 3.4 External preference map, indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the ten sensory attributes. The pear genotypes were: Rosemarie (A); 3D-13-34 (B); 3D-15-35 (C); Flamingo (D); 15A-5-20 (E); Red d'Anjou (F); 3D-41-5 (G); 3D-37-38 (H); 3D-67-5 (I); Bon Rouge (J); and Packham's Triumph (K). The consumer results were: Preference of appearance (PrefAppearance), preference of taste for peeled (PrefPeeled) and unpeeled samples (PrefUnpeeled). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the trained panel and instrumental data (x space).

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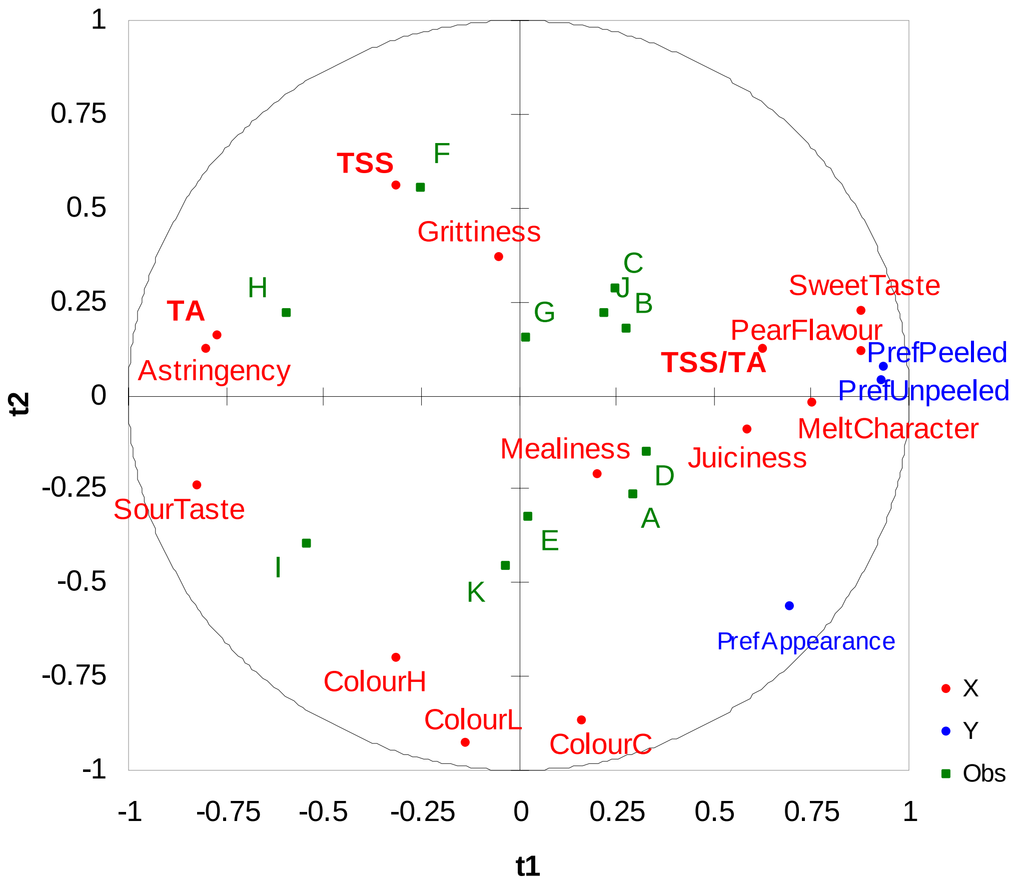

Figure 3.5 External preference map, excluding maturity indicators, indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the ten sensory attributes. The pear genotypes were: Rosemarie (A); 3D-13-34 (B); 3D-15-35 (C); Flamingo (D); 15A-5-20 (E); Red d'Anjou (F); 3D-41-5 (G); 3D-37-38 (H); 3D-67-5 (I); Bon Rouge (J); and Packham's Triumph (K). The consumer results were: Preference of appearance (PrefAppearance), preference of taste for peeled (PrefPeeled) and unpeeled samples (PrefUnpeeled). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the trained panel and instrumental data (x space).

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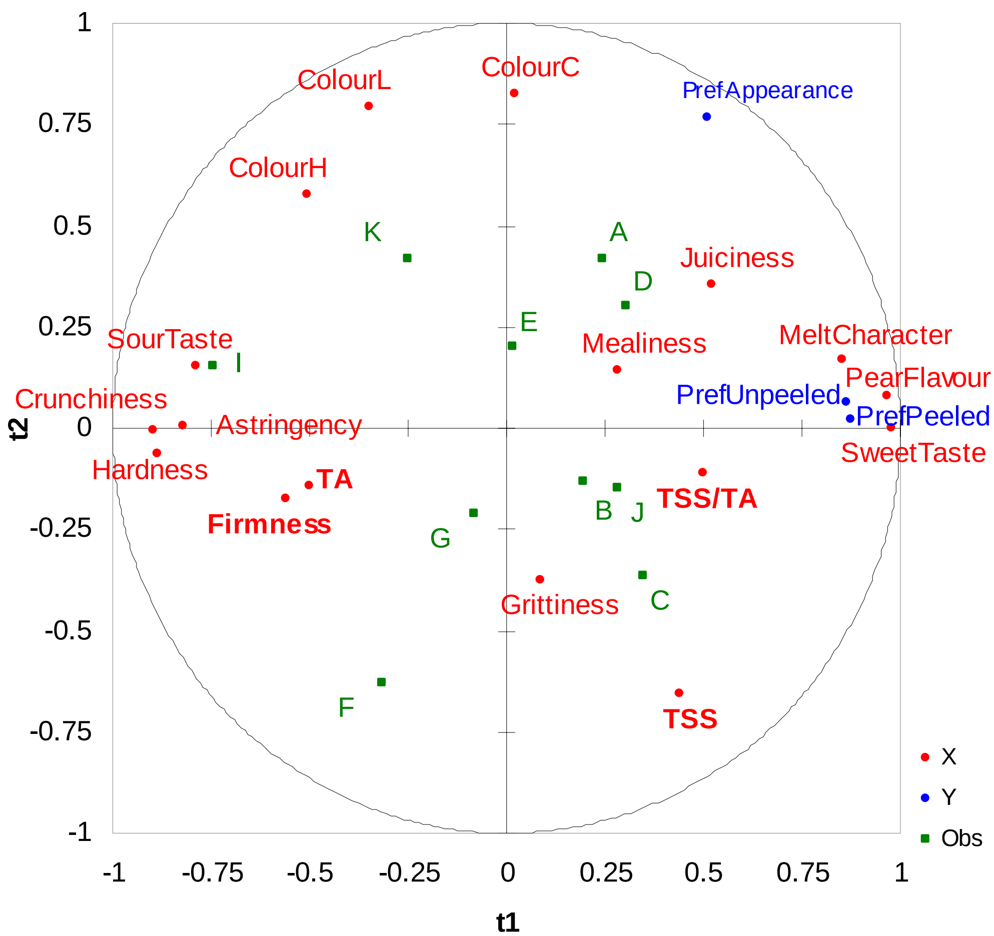

Figure 3.6 External preference map excluding genotype 3D-37-38 (H), indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the ten sensory attributes. The pear genotypes were: Rosemarie (A); 3D-13-34 (B); 3D-15-35 (C); Flamingo (D); 15A-5-20 (E); Red d'Anjou (F); 3D-41-5 (G); 3D-67-5 (I); Bon Rouge (J); and Packham's Triumph (K). The consumer results were: Preference of appearance (PrefAppearance), preference of taste for peeled (PrefPeeled) and unpeeled samples (PrefUnpeeled). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the trained panel and instrumental data (x space).

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CHAPTER 4

Consumer preference of pears with emphasis on overall eating quality

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ABSTRACT

The pear industry in South Africa needs to stay competitive in overseas markets. New cultivars should fill and extend gaps in the marketing strategy of exporters and in local markets. In addition, new cultivars should meet the needs and expectations of consumers in order for the product to be successful in the market. Every consumer has their own idea about what an acceptable or high-quality product represents. This perception results from the judgment of several factors including size, colour, flavour, aroma and texture. The aim of this study was to assess the preference of South African consumers for pear appearance and taste.

This study assessed consumer preference for appearance and taste of eleven different pear genotypes over two assessment dates. Approximately 200 consumers participated in the study. A representative sample of each genotype was presented to the consumers who were asked for their degree of liking of the external appearance of the pear genotypes, including the colour and the shape. Preference was the highest for lightly blushed skin colour but the yellow or green cultivars also received a high preference. There was a dislike for brown and dark red colours as well as pears with a round shape. This is in agreement with previous studies done internationally. A segment from each genotype was also presented to the consumers for analysis of degree of liking of taste. The panel of trained judges analysed ten sensory characteristics on the same genotypes over the same time period. Maturity indexing was performed by measuring the firmness, total soluble solids and the titratable acidity. Correlations between the types of data were discovered, the most noteworthy being the significant positive correlation between the consumer's preference for taste and the sensory attribute pear flavour. Other important attributes were juiciness, sweetness and melt character. These can be seen as the motivating force for preference among the consumers included in this study. A high firmness and mealiness correlated negatively with the consumer's preference of taste. Results obtained can be used to verify the breeding objectives of the Agricultural Research Council (ARC) pear breeding program. The data indicate that local consumer groups can be used to assess the quality of new cultivars for the export market.

Key words: *Pyrus communis*, appearance, colour, taste, texture

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INTRODUCTION

Production of European pears (*Pyrus communis* L.) in South Africa increased up to 2002 due to the planting of red blushed cultivars such as Rosemarie, Flamingo and Forelle (Human, 2002). This range of blushed cultivars was harvested from early to late season which gave South Africa a strong marketing advantage (Human, 2002). 'Flamingo' has since, for various reasons, completely disappeared from the scene while 'Rosemarie' production is also decreasing mainly due to poor colour development. Hence, there used to be a long season, but not any more with only 'Forelle' produced in substantial quantities. The search is therefore on via the South African Agricultural Research Council's pear breeding programme for an early season blush pear replacement.

Blush pears are thought to be sought after in the European export market. However, previous studies analysing New Zealand and Australian consumer's preference of ideal pear characteristics indicate that the traditional yellow and green skin colours are preferred (Gamble *et al*., 2006; Kappel *et al.*, 1995). A slight red blush may also be acceptable (Kappel *et al.*, 1995). Another factor to consider with regard to consumer preference of appearance is fruit shape. Generally, the preferred fruit shapes are intermediate-straight or elongate-concave (Gamble *et al*., 2006; Kappel *et al.*, 1995).

Although external factors such as skin colour can influence the initial reaction to fresh fruit, cultivar developers have to keep in mind that the ultimate judgement cannot be made until the fruit is tasted (Kingston, 1991). While novelty may encourage initial purchasing, a good flavour is important to ensure continued purchasing (Gamble *et al*., 2006). Hence, it is of great importance to assess consumer preference for taste and keep the main drivers of preference in mind during the breeding of new cultivars. In general, European pears with a good eating value have a texture that is juicy, buttery and melting with a strong pear flavour but there are consumers that prefer pears with a crispy and juicy texture to a buttery and melting one (Hoehn *et al*., 1996). With regards to defining texture properties of ripe pears, it is important to note that chemical or physical analysis can not replace sensory analysis (Eccher Zerbini, 2002). If the consumer's expectations are met once they have purchased and consumed the fruit, the consumers will then maintain their assurance in the supplier and continue to purchase and pay maximum prices for the product (Kingston, 1991).

The aim of this study was to determine the preference of taste among South African pear consumers. Preference of skin colour, or appearance, was also analysed by presenting photographs of each of the genotypes to the consumers. There were only two assessment

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dates, approximately four weeks apart, hereby, allowing each pear cultivar to reach optimal maturity for evaluation within this period. Descriptive sensory analysis was performed using a trained panel of judges analysing ten sensory characteristics of pears. The questionnaires given to the consumers contained a section where they were asked to select attributes that best describe their ideal pear. These answers were then used to compare with the results from the consumer sensory analyses as well as the descriptive sensory analyses.

MATERIALS AND METHODS

Genotypes

Ten European pear (*Pyrus communis* L.) and one Asian pear (*P. pyrifolia* Nakai) genotypes consisting of nine established pear cultivars and two selections were selected for this study. The genotypes that were selected for this study were mainly based on good eating quality and taste. The pears studied included two blushed cultivars; Rosemarie and Cheeky, two fully green cultivars; Packham's Triumph and Concord, two fully green selections; 4A-88-18 and 3D-44-3, three russeted (or brown) cultivars; Golden Russet Bosc, Hosui (*P. pyrifolia*) and Abate Fetel, a fully red cultivar; Red d'Anjou, and a fully yellow cultivar; Bon Chrétien. 'Packham's Triumph', 'Concord', 'Abate Fetel' and 'Bon Chrétien', are currently important established cultivars available in the marketplace. The characteristics of these pears were used as a benchmark for the choice of the selections present this study. Figure 4.1 shows photographs of each genotype used in the study.

Harvest

All selected genotypes were harvested at their optimum firmness, between 6 - 8 kg. The pears were sourced from Elgin (lat.: 34º10'S, long.: 19º03'E) in the Western Cape province of South Africa. All fruit was harvested within one month from 9 January 2008 to 15 February 2008. After harvest, fruit was kept in cold storage at -0.5 °C at ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa and remained there until all the genotypes were harvested and ready for analysis. Assessments were conducted on two dates, 17 March and 14 April 2008, approximately four weeks apart in order to perform the analyses on each genotype at their optimum maturity and best eating quality. Four days prior to the commencement of the analyses, 31 pears were randomly selected from each genotype and placed in a 15 °C ripening room. The fruit was used for maturity indexing, descriptive sensory analysis and consumer

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sensory analysis. As the pears were removed from this storage to be prepared for analyses, each was uniquely numbered.

Experimental design

For each of the two assessment dates, a representative pear of each genotype was displayed on a white background and photographed. Thereafter, the latter pears were used for instrumental colour measurement. Thirty one pears from each genotype were randomly selected at each assessment date for maturity indexing and sensory analysis. First, six out of the 31 pears were selected and each divided into quarters; one quarter from each pear was used for maturity indexing and the remaining three quarters for the descriptive sensory analysis of the trained panel. Three panel members received samples from the same pear. As there were nine panel members, six pears were used per assessment date (three pears for each of the two replications per assessment) for both the maturity indexing and the descriptive sensory analysis. The pears were all uniquely numbered before being divided and thereby the results from each analysis can be followed and compared. The remaining 25 pears per genotype were also divided into quarters and each consumer received one quarter of each pear genotype to analyse for degree of liking. Hence, each genotype was tasted by 100 consumers at each assessment date.

Descriptive sensory analysis

The sensory panel consisted of nine assessors. The panel was trained using the consensus method as described by Lawless and Heymann (1999) and tested for consistency. A 100 mm unstructured line scale, where the left side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity, was used for each attribute intensity analysis. A sample from each genotype was used to train the panel for the sensory attributes. The judges agreed on a consensus list of attributes for describing pear flavour and texture. The definitions for the sensory attributes are given in Table 4.1; these are similar to those used by Jaeger *et al*. (2003).

The eleven pear genotype samples were analysed during four sessions (two replications on two assessment dates). The panellists were seated individually at sensory booths, which were light and temperature controlled at 21 ºC. Pear samples were each coded with a three digit random code and presented on Petri dishes (Kimix, South Africa) in a complete randomised order. Scores for the sensory attributes of 'Bon Chrétien' were agreed upon by the panel before the onset of the assessment of the other genotypes. A sharp knife was

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available to the judges who were asked to remove the pear's skin and core. Each sample was approximately 1.5 cm wide. Flavour and texture attributes were assessed on the pear flesh and not the skin peel. Samples were served at room temperature (21 ºC) and still water and unsalted biscuits (Woolworths, South Africa) were available for the judges to clean their palates between samples.

Consumer sensory analysis

One hundred consumers at each assessment date were asked to complete standard questionnaires analysing all eleven pear genotypes according to overall degree of liking. The analysis consisted of three questionnaires; Q1, Q2 and Q3. The preference for taste was judged in Q1, the preference for appearance of the photographs were assessed in Q2 and in Q3 a number of questions relating to the consumer's perception of the ideal pear was asked. The samples were presented to the consumers with the peel facing them. The consumers did taste the peel together with the flesh. A complete block design in randomised order was used. Each treatment was presented in an open Petri dish (Kimix, South Africa) with a three digit random code. In this test, the consumer was asked to indicate which term best describes his/her attitude towards the products being tasted using the nine-point hedonic scale with the categories ranging from 9 (like extremely) to 1 (dislike extremely) with 5 being neutral (neither like nor dislike) (Lawless and Heymann, 1999). This gives an indication of preference as well as acceptance. Still water and unsalted biscuits were available for the consumers to cleanse their palates between samples. The photographs of the whole pears that were presented on the second questionnaire were evaluated according to degree of liking of appearance on the nine-point hedonic scale. A list of attributes appropriate for pears was also given to the consumers and they were asked to indicate which attribute/s they most prefer to describe their ideal pear. They were also asked which cultivars they would usually purchase or consume.

Physical measurements

The colour of each pear was measured using a handheld colorimeter (Nippon Denshoku Model HR-3000, Tokyo, Japan) at the mid point between the stem and the calyx or at the reddest position on pears with a red colouring. The lightness (L*), chroma (C*) and hue angle (H) were recorded. Flesh firmness (kg) was measured on one side of the fruit using a penetrometer (Southtrade fruit pressure tester, Model FT 327, Alphonsine, Italy) fitted with an 8 mm probe. Hereafter, the pears were divided into quarters. Three of the quarters from each pear were used for the descriptive sensory analysis. The remaining quarter from each

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pear was placed in a juice extractor and the juice used to determine the total soluble solids (TSS) and the titratable acidity (TA). TSS, which represents the fruit's sugar content, was measured from the juice of each pear sample using a calibrated hand held refractometer (TSS 0-32%, Model N1, Atago, Tokyo, Japan). TA was determined using an automated titrator (Tritino 719S and Sample Changer 674, Metrohm Ltd., Herisau, Switzerland) by titrating 5 g of juice from each pear sample with 0.1 N NaOH to an end point pH of 8.2. The TA is expressed as percentage malic acid. The soluble solids and acidity ratio was also calculated by dividing the TSS value with the TA value.

Statistical procedures

The three sets of data were subjected to an 11 x 2 factorial analysis of variance (ANOVA) in a complete randomized design using SAS statistical software (SAS, Version 9, 1999, Cary, North Carolina). Shapiro-Wilk's test was performed on the residuals to test for non-normality (Shapiro and Wilk, 1965). In the cases of significant evidence against normality, which was due to skewness, outliers were identified and removed until the residuals were symmetric or significantly normal (Glass *et al*., 1972). Means were compared with the Student's t-LSD (Least Significant Difference) at a 5% significance level. The Cultivar x Time combination means of all the data sets was combined. XLStat version 2007 software (Addinsoft, Version 2007, Paris, France) was used to perform the Pearson's correlation between variables. External preference mapping was performed by regressing the consumer data (y space) with the physical and the sensory attribute values (x space) using Partial Least Squares (PLS) modelling.

RESULTS AND DISCUSSION

The analyses were performed on two different dates approximately four weeks apart. The overall mean values of the results for the two dates will be discussed as no significant interaction was observed between genotype and assessment date.

Consumer demographics

The 200 consumers taking part in this section of the study, over the two assessment dates, comprised of mainly females with only 22% males. The majority of the consumers (55%) consume pears twice per month and only 15% never consume pears. Ninety-one percent were

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between the ages of 18 and 30 and therefore only a small number of people that fell into the older age categories took part.

Colour

The colour of a representative of each genotype was measured at the mid point between the calyx and the stem or on the reddest position for pears with a red colouring. The chroma, lightness and hue angles were measured and can be seen in Table 4.2.

A low hue value indicates a red colour peel, a value above 100 indicates a green peel and values slightly lower than this would be yellow and then brown colours. '3D-44-3', 'Packham's Triumph', 'Concord' and '4A-88-18' are all green pears with a hue value greater than 105. However, Bon Chrétien, a yellow pear, did not differ significantly from '4A-88-18'. 'Abate Fetel' and 'Hosui' did not differ in hue from 'Bon Chrétien' or from 'Golden Russet Bosc', which is even more russetted and therefore more brown in colour. 'Rosemarie', 'Cheeky' and 'Red d'Anjou' were the only genotypes with a red over colour and did not differ significantly from each other.

'Concord' and 'Packham's Triumph' were the highest in chroma and differ significantly from the other genotypes except for '3D-44-3', 'Bon Chrétien' and '4A-88-18'. These latter three genotypes did not differ significantly in chroma from 'Rosemarie' and 'Cheeky'. 'Abate Fetel' had a comparable chroma to these two genotypes. 'Hosui' and 'Golden Russet Bosc' had a low chroma, but higher than 'Red d'Anjou', which had significantly the lowest chroma.

'Bon Chrétien' and 'Packham's Triumph' have the highest lightness but the latter genotype is not significantly higher than 'Concord', '4A-88-18', 'Abate Fetel', '3D-44-3' and 'Hosui'. '4A-88-18', 'Abate Fetel', '3D-44-3' and 'Hosui' were also not significantly different from 'Golden Russet Bosc'. All these apart from '4A-88-18' do not differ significantly from 'Rosemarie'. 'Golden Russet Bosc' and 'Rosemarie' do not differ significantly from 'Cheeky' and 'Cheeky' was not significantly higher than the genotype with the lowest lightness, 'Red d'Anjou'.

Preference of appearance

The acceptability for appearance was measured on a scale from one, which is equal to dislike extremely, to nine, which is equal to like extremely, with 5 being neutral (neither like nor

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dislike). The overall mean values for the total group's degree of liking of the appearance of the pears are shown in Table 4.2.

The genotypes that received overall means of above 6.0 can be seen as having a positive liking according to their appearance. 'Rosemarie' received the highest preference over all the genotypes with a value of 7.5, which is in the like moderately category. 'Packham's Triumph', '3D-44-3' and ''Bon Chrétien' also received high scores for degree of liking between 6.0 and 7.0. The latter two genotypes did not differ significantly from each other but 'Packham's Triumph' did receive a higher liking than them. 'Cheeky' and 'Concord' did not differ significantly and scored in the neutral category, between 5.0 and 6.0. 'Red d'Anjou' and 'Abate Fetel' received values just under 5.0 and a negative liking resulted. The latter genotype did not differ significantly from 'Golden Russet Bosc' and this genotype was not significantly higher than '4A-88-18'. 'Hosui' received the lowest preference over all the genotypes with a value of 3.2, which is in the dislike moderately category.

According to these results, the consumers preferred green, blush (yellow and red combination) and yellow colours. Full red, brown and brown and green combinations were not accepted. Turner *et al*. (2005) found that American consumers preferred a yellow pear with a blush colouring over a russetted. Kappel *et al*. (1995) found that a blush colouring was preferred but if the blush covering increased, the preference decreased, which could explain the dislike for full red pears. This decrease in preference could be due to the increase of blush colour covering the ground colour and the consumers then not being able to assess the ripeness of the pear. The colour brown, regardless of fruit shape, was also not well liked by the consumers, for example, the genotypes 'Abate Fetel' (which contains brown markings), 'Golden Russet Bosc' and 'Hosui'. The green selection '3D-44-3' compared well to established cultivars but the selection '4A-88-18' was disliked even though it has a green colouring. The dislike seems to be due to the shape of the pear. This shows that the form of the pear has an influence on the consumer. Round pears were rejected such as 'Red d'Anjou', '4A-88-18' and 'Hosui'. 'Abate Fetel' was not favoured by the consumers and it could be because of the elongated shape or the combined green and russet colouring which was not popular. The 'typical pear' shape was preferred by the consumers. This is similar to what was found by Turner *et al*. (2005) namely that a 'Williams Bon Chrétien' shape was preferred.

The chroma value, or the brightness of the pear, is also important (Kappel *et al*., 1995). A weak positive correlation was found between consumer preference of appearance and the colour measurement chroma (C*) ($r=0.534$; $p=0.011$). This suggests that consumers

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preferred an intense or brighter colour and disliked a dark and dull peel. It has also been found in other studies that brighter coloured fruit is preferred by consumers over fruit that has a duller complexion (Baarschers, 1996; Sanderson, 2007).

Sensory characteristics

The trained panel analysed different texture characteristics (Table 4.1) on the 11 pear genotypes. The mean values for each characteristic from the two replications at each assessment date are shown in Table 4.3.

Important characteristics for pears are pear flavour, sweet taste, firmness, melt character and juiciness (Eccher Zerbini, 2002). If a genotype has high values for pear flavour, sweet taste, melt character and juiciness and a low value for hardness, it is expected that the genotype will be highly favoured among consumers (Predieri *et al*., 2005).

'Bon Chrétien' and 'Cheeky' had the highest pear flavour overall apart from 'Rosemarie' which did not differ significantly from 'Cheeky'. 'Golden Russet Bosc' had a much lower value to these and '3D-44-3', 'Abate Fetel' and 'Concord' was not significantly lower than this genotype. These three genotypes were also not significantly different to '4A-88-18'. 'Packham's Triumph' was slightly lower but not significantly different from '4A-88-18'. 'Hosui' and 'Red d'Anjou' had the lowest perceived pear flavour overall.

'Cheeky' and 'Bon Chrétien' also had the highest perceived sweet taste together with 'Hosui'. 'Cheeky' and 'Bon Chrétien' did not differ significantly from '3D-44-3' and 'Bon Chrétien' also did not differ significantly from 'Concord', 'Abate Fetel' and 'Rosemarie'. These genotypes, however, were not significantly higher than 'Packham's Triumph' and 'Golden Russet Bosc' which in turn did not differ significantly from the second lowest measured sweet taste of ''4A-88-18'. 'Red d'Anjou' had the lowest perceived sweetness with a value of more than 10.

'Hosui' had the hardest perceived texture together with 'Red d'Anjou'. 'Concord' and 'Packham's Triumph' were a softer texture but still harder than most of the genotypes although 'Packham's Triumph' did not differ significantly from '3D-44-3', '4A-88-18' and 'Abate Fetel'. 'Golden Russet Bosc', 'Cheeky' and 'Rosemarie' had a much softer texture and the genotype with the lowest perceived hardness, 'Bon Chrétien', was not significantly softer than 'Rosemarie'.

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There was a wide range of melt character between the genotypes, ranging from 74.5 ('Bon Chrétien') to 4.4 ('Red d'Anjou'). 'Rosemarie' and 'Cheeky' had a much lower meltiness than 'Bon Chrétien' but would still be considered to have a high melt character. '3D-44-3', '4A-88-18' and 'Abate Fetel' was even lower and the latter did not differ significantly from 'Golden Russet Bosc'. The remaining four genotypes had very low meltiness (below 20) and were firm pears, which can be seen in the perceived hardness measurements. 'Packham's Triumph' and 'Concord' did not differ significantly but the former pear did differ from the genotypes with the lowest perceived melt character, 'Hosui' and 'Red d'Anjou'.

There were a number of pears with a high juiciness. 'Bon Chrétien', 'Hosui', 'Cheeky' and 'Rosemarie' had the highest perceived juiciness. The next genotype, 'Abate Fetel' had a slightly lower measurement and did not differ significantly from '4A-88-18'. The latter genotype was not significantly higher than 'Packham's Triumph', '3D-44-3' or 'Golden Russet Bosc' which all had low perceived juiciness. The last two mentioned genotypes did not differ significantly from 'Concord' and this was not significantly different form the genotype with the lowest perceived juiciness, 'Red d'Anjou'.

The remaining attributes measured during descriptive sensory analysis are generally thought to be negative characteristics relating to pears, such as mealiness and high sourness (Boylson *et al*., 1994) and in some cases grittiness (Jaeger *et al*. 2003). These genotypes, in general, were not very mealy. Only 'Golden Russet Bosc', which had the highest perceived mealiness, and 'Bon Chrétien' had values above 10. The rest of the genotypes ranged from 6.1 ('Concord') to the lowest overall, 'Hosui', which had virtually no perceived mealiness (0.4).

'Rosemarie' had the highest sourness together with 'Packham's Triumph' and 'Bon Chrétien'. The latter two genotypes did not differ significantly from 'Red d'Anjou'. This genotype together with 'Bon Chrétien' was not significantly higher than 'Golden Russet Bosc' and 'Cheeky'. 'Hosui', 'Concord', '4A-88-18' and 'Abate Fetel' had a lower sourness but 'Cheeky' did not differ significantly from this group. 'Hosui' was also not significantly different to 'Golden Russet Bosc' and this group was also not significantly higher than the genotype with the lowest perceived sour taste overall, '3D-44-3'.

As with mealiness, the genotypes, generally, did not have perceived grittiness. The grittiness ranged from 24.7 to 7.5. 'Golden Russet Bosc' had the highest grittiness followed by 'Concord' and '4A-88-18'. These were the only genotypes with values above 15, and

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could probably be seen as the only ones with a noticeably gritty texture. 'Abate Fetel' and '3D-44-3' were lower but not significantly different to '4A-88-18'. 'Hosui', 'Red d'Anjou' and 'Bon Chrétien' were lower still but not differing significantly from 'Packham's Triumph' and 'Rosemarie'. The latter two genotypes together with 'Bon Chrétien' were however not significantly higher than the lowest perceived grittiness of 'Cheeky'.

Physical measurements

The instrumental measurements taken were firmness, TSS, TA and the TSS/TA ratio was calculated. The mean values of these measurements are shown in Table 4.4. There do not seem to be large differences between the genotypes for the different measurements. TSS, TA and firmness should, in theory, correlate with the perceived sweet taste, sour taste and hardness, respectively, of the trained panel but this is not usually the case (Watada *et al*., 1984; Hampson *et al*., 2000). Firmness and hardness had a strong correlation (r=0.811; p=0.002), sour taste and TA also had a positive correlation (r=0.786; p=0.004) but sweet taste and TSS did not correlate (r=0.109; p=0.751).

The firmness measured did not show much variation among the genotypes. The genotype with the highest firmness was 'Red d'Anjou'. This was, however, not significantly different to the rest of the genotypes apart from 'Rosemarie' and 'Bon Chrétien'. 'Bon Chrétien' was measured as having the lowest firmness.

The TSS ranged between 15.2 and 12.3 ºBrix and only 'Packham's Triumph' and 'Rosemarie' were significantly different to each other. 'Packham's Triumph' had the highest TSS measurement and 'Rosemarie' the lowest.

The TA values also showed a small range between 0.29 and 0.14 % malic acid. 'Packham's Triumph' had the highest TA measurement but did not differ significantly from 'Bon Chrétien', 'Red d'Anjou', 'Golden Russet Bosc', 'Rosemarie', 'Hosui' and 'Concord'. 'Abate Fetel' had the lowest measured TA but not significantly lower than 'Cheeky', '3D-44-3' and '4A-88-18'.

The TSS/TA ratio explains the sweet and sour balance in pears. For the right sweet and sour balance to occur, a relatively high ratio is required (Chen *et al*., 2007). 'Abate Fetel' had the highest ratio at almost 100 and 'Red d'Anjou' the lowest 49.5. 'Abate Fetel' did not differ significantly from '3D-44-3' and 'Cheeky'. These two genotypes did not differ significantly from the rest except for the three lowest ratios of 'Bon Chrétien', 'Rosemarie'

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and 'Red d'Anjou'. Generally, a high acidity would result in a low acceptability (Boylson *et al.*, 1994) but if the genotypes have a high TSS and sweet taste, such as in the case of 'Packham's Triumph' and 'Rosemarie', it results in a relatively high TSS/TA ratio which is more favourable.

Preference of taste

The acceptability for taste was measured on a scale from one, which is equal to dislike extremely, to nine, which is equal to like extremely, with 5 being neutral (neither like nor dislike). The liking of the taste includes the flavour or aroma and the texture of the fruit. Consumers evaluated the overall taste of each pear genotype. The degree of liking is shown in Table 4.5 for the total group.

When viewing the results of all the physical and sensory attributes together, 'Bon Chrétien' seems to have all the favourable attributes and low values of the negative attributes. This genotype had the highest values for pear flavour, sweet taste, melt character and juiciness and the lowest value for hardness and a relatively low value for grittiness. Only sour taste and mealiness had high scores which would not be favourable. From these results it would be expected that 'Bon Chrétien' would have the highest preference for taste by the consumers. The results show otherwise, 'Rosemarie' and 'Cheeky' have significantly the highest preference in the like slightly category with 'Concord' slightly less and 'Bon Chrétien' in the third highest group all in the neutral degree of liking category together with 'Packham's Triumph' and 'Golden Russet Bosc'. 'Bon Chrétien' has a relatively high perceived mealiness compared to the other genotypes. This is a negative attribute and could be the reason for the genotype not performing as well as expected. This genotype could have been at an overripe stage at the time of the assessments which could negatively influence the results. The next group, with the second lowest degree of liking ranged between 5.0 and 4.7. These genotypes were '4A-88-18', '3D-44-3', 'Abate Fetel' and 'Hosui' and did not differ significantly. 'Red d'Anjou' was significantly lower than this group and had the lowest preference over all the genotypes with a score of 3.6 or dislike moderately. The two new selections, '4A-88-18' and '3D-44-3' did not compare well to the established cultivars but 'Cheeky' compared very well and can be seen as one of the best genotypes regarding taste.

In the previous years' research (Chapter 3), the pear samples were served to the consumers as peeled and unpeeled segments. The genotypes that coincide with last years study are 'Red d'Anjou', 'Rosemarie' and 'Packham's Triumph'. 'Cheeky' was also included but was at that stage not yet released as a cultivar and was then named '3D-13-34'. By

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comparing the results of these unpeeled samples with the current year's results, a few similarities were found such as consumers had the highest liking for the blush pear, 'Rosemarie'. The green cultivar, 'Packham's Triumph' also received a value between 5.0 and 6.0. However, 'Red d'Anjou' had a much lower degree of liking in this study than in the previous chapter. 'Red d'Anjou' was in the dislike slightly category with a score of 4.7. 'Cheeky' on the other hand, received a higher degree of liking in this study with a value of 6.7 compared to 5.8 previously. Apart from these differences, the results overall are consistent with the previous years research (Chapter 3). The overall preference was for a sweet tasting and strong flavoured pear with a soft and juicy, but not mealy texture and the skin colour must have a light green or yellow background with a bright red or pink blush.

The results of the consumer's degree of liking of appearance and of taste showed a weak positive correlation (r=0.538; p=0.010) with each other. This does not necessarily mean that the degree of liking of the peel colour has an influence on the taste perception of consumers. It could either be a coincidence, the consumers could be making assumptions based on past experiences (Jaeger *et al*., 2003; Kingston, 1991), or the consumer could know which colour pear they normally enjoy eating and therefore judged the appearance by these standards. The scatter plot of the taste and appearance results is shown in Figure 4.2. The external appearance of both 'Red d'Anjou' and the selection '3D-44-3' has a higher acceptance than their eating quality. The opposite is true for 'Golden Russet Bosc' and 'Hosui'. Other than these mentioned genotypes, the flavour and the appearance have a similar liking by the consumers.

The consumers were asked a number of questions regarding their preference of pear attributes and colours. The answers given regarding their ideal pear showed a similar outcome to that of the analysis of the photographs. When asked which attributes is most preferred in a pear, the majority answered juicy and sweet. Out of approximately 200 consumers the most frequently mentioned attributes were juicy (19%) sweet (18.5%), not mealy (15%) and soft (14%). Jaeger *et al*. (2003) received answers similar to these from New Zealand consumers, apart from a number of them answering firm or crisp/crunchy as desirable sensory characteristics. The Asian pears that are more prevalent in these regions have these characteristics and may be the reason for this result. Very few answers (54) were given when asked which cultivars consumers usually purchase or consume. Of these answers only 28 specific cultivar names were given. 'Forelle', which is a blush pear, was mentioned the most (13) as well as 'Bon Chrétien' (7) but 'Don't know' was answered the most (18) or names of shops (5) or the colour the pears (3) were given. Jaeger *et al*. (2003) also found that consumers were not aware of cultivar names in New Zealand. As the most widely known

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pear cultivar of this group of consumers is 'Forelle' and the most liked attributes are sweet and juicy; this agrees with the results from the photographs; 'Rosemarie' was the most liked which is also a blush pear, like 'Forelle', and its texture is also sweet and juicy. These answers are similar to those given by the consumers in the previous study (Chapter 3) and also correspond to the most important sensory traits in pears that were found by Kappel *et al*. (1995) and Predieri *et al*. (2002).

Drivers for degree of liking

Preference mapping is a statistical tool that can clarify differences in consumer liking for the same product. For example, what one consumer likes, another may dislike (Harker *et al*., 2008). The map is formed from consumer hedonic responses, and then instrumental or sensory attributes are projected onto the map according to correlation against the preference dimensions (MacFie and Hedderly, 1993). Overall tendencies and patterns can be observed the drivers for preference recognised. An external preference mapping was performed and shown in Figure 4.3 and Figure 4.4. The results from all the analyses performed were calculated together. The maturity indicators (firmness, hardness, crispness and crunchiness) were included in Figure 4.3 but not in Figure 4.4 as to assess the drivers of liking independent of maturity. Overall there was not a significant interaction between genotypes and assessment date. However, genotype means for both assessment dates are provided due to some revealing tendencies that were observed.

Of the characteristics analysed, seven had a relatively strong correlation with the consumer's preference of taste. Crispness, crunchiness and hardness obtained similar values for all the cultivars by the judges. These all had the same relatively strong negative correlation with the degree of liking for taste ($r=-0.652$; $p=0.001$; $r=-0.651$; $p=0.001$ and $r=-0.649$; $p=0.001$, respectively) confirming that the consumer prefers a softer pear to a firmer or what is seen as an under ripe pear (Jaeger *et al*., 2003). These three characteristics are maturity indicators. Some of these pears could have not been at their optimum maturity and therefore still too hard for acceptability, for example, 'Red d'Anjou' which at the first assessment date was close to these attributes, thereby indicating a positive correlation (Fig. 4.3). The second assessment date of 'Red d'Anjou' is situated closer to the centre of Figure 4.3 as this genotype increased in maturity and in acceptability. 'Packham's Triumph' had a high TA level at the first assessment date (situated close to TA) and decreased to the second assessment date (moved closer to TSS and to PrefTaste) (Mann and Singh, 1985) thereby increasing the acceptability. If the assessments on these specific pears were performed at a later date, a different acceptability may have resulted.

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Pear flavour (r=0.709; p≤0.001), sweet taste (r=0.484; p=0.023), melt character (r=0.478; p=0.024) and juiciness (r=0.443; p=0.039) all had positive correlations with the consumer's preference of taste. The strongest and most noticeable of these was pear flavour. All these characteristics, but especially pear flavour, are important factors for eating quality of pears (Eccher Zerbini, 2002) and are drivers for the consumer's preference as it can also be seen in the partial least squares (PLS) of the overall results in Figures 4.3 and 4.4. High correlations have been found between fruit acceptance and perceived aroma (Rapparini and Predieri, 2003).

Grittiness and mealiness were not prevalent in any of the pears. 'Golden Russet Bosc' had the highest perceived grittiness but also the highest value for mealiness thereby situated in the vicinity of these attributes (Figure 4.3). 'Abate Fetel' and 'Hosui' are also situated here. 'Abate Fetel' has the highest TSS/TA ratio and a high juiciness causing the slight movement to the right side. 'Hosui' has a high sweet taste, juiciness and perceived hardness causing the genotype to be situated in the middle of these attributes. As stated previously, the perceived sour taste and TA measurements did correspond relatively well and therefore these attributes are situated close by in Figure 4.3. TSS and sweet taste did not correlate (r=0.109; p=0.751).

There are two groupings in this preference map, the first one being in the right half including genotypes 'Bon Chrétien', 'Rosemarie' and 'Cheeky' of both assessment dates and the second assessment date of 'Packham's Triumph'. The second group is the rest of the genotypes except for the first assessment date of 'Packham's Triumph' and 'Red d'Anjou'. The first group is situated closest to 'PrefTaste' and can be seen as the most liked pears overall. These genotypes had high acceptability for both taste and for appearance. The mean values were between 5.8 and 7.5 for appearance (Table 4.2) and 5.9 and 6.8 for taste (Table 4.5). The second group lie further away and it does not necessarily mean that these are unfavourable genotypes but other factors that are unfavourable for the consumers caused them to be drawn further from 'PrefTaste' and the attributes seen as the drivers for preference. An example is 'Concord' which had a high grittiness and relatively high values for crispness, crunchiness and hardness. The selection '3D-44-3' had a high rating for appearance but the genotype is not situated near to 'PrefAppearance'. The taste was not well liked by the consumers.

There are various differences between Figure 4.3, including maturity indicators, and Figure 4.4, excluding the maturity indicators. The measurements by the consumers for the

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degree of liking for the appearance and the taste of the pears both lie in approximately the same positions as they did including the maturity indicators. Melt character, pear flavour and the chroma measurement of colour had the greatest association with the consumer's preference for taste. Juiciness and sweet taste did not have such a high influence. 'Bon Chrétien' still has the highest correlation of all genotypes but the second assessment of 'Bon Chrétien' is not as closely situated to degree of liking for taste (it moved towards mealiness). Maturity indicators had a high correlation with the first assessment of 'Red d'Anjou', but without maturity indices, this genotype has no strong correlation with the other sensory attributes; both the assessments lie together away from other measurements. The sensory attributes that are expected to respectively increase or decrease with maturity (excluding the firmness of the fruit) are mealiness and juiciness. The mealiness tends to increase with age (Martin *et al*., 2003) and the juiciness can either increase (Chen and Mellenthin, 1981) or decrease depending on the fruit and storage conditions (Chen *et al*., 1983) (decrease when fruit become mealy). Juiciness moved away from the positive cluster of measurements as did sweet taste. Mealiness was strongly correlated with the first assessments of '4A-88-18', 'Golden Russet Bosc' and 'Abate Fetel'. Without the maturity indices these are still correlated but not as strongly and genotypes '3D-44-3' and 'Cheeky' were then strongly correlated. The titratable acidity stayed in approximately the same area but the total soluble solids measurement moved away into the lower half of the graph.

A PLS performed on the instrumental colour measurements and the consumer's preference of appearance data alone is shown in Figure 4.5. The graph confirms the chroma and appearance preference correlation ($r=0.534$; $p=0.011$) and speculations of this data discussed previously. The chroma measurement lies closest to the 'PrefAppearance'. This measurement therefore has the greatest influence on the consumer. The other two measurements have less influence and lie further away on the graph. There are no strong associations between any of the genotypes and 'PrefAppearance' evident but genotypes 'Cheeky' and 'Rosemarie' are situated the closest and were the most preferred by the consumers. These also seem to have a strong negative association with hue angle. This is because they have a low hue value. Despite consumer preference for certain skin colour being apparent, hue angle ($r=-0.033$; $p=0.883$) and lightness ($r=0.201$; $p=0.369$) do not correlate with consumer preference for appearance. This is because the relationship between hue angle and lightness with preference is non-linear; consumers preferred blushed pears with intermediate hue angles and lightness values to green/yellow/brown pears with high hue angles and full red pears with low hue angles (Kappel *et al*., 1995). In addition, fruit shape appears to have an overriding effect on the degree of liking of skin colour (Gamble *et al*., 2006).

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CONCLUSIONS

Concluding from all information gathered with this research, the ideal pear has a yellow, green or light blushed colour, a conventional 'pear shape', a strong typical pear aroma, a soft texture and prominent meltiness characteristics. Juiciness and sweetness is of lesser importance. The appearance results showed consistency with the findings of Kappel *et al*. (1995) who found a preference for elongate-concave shaped yellow pears while a slight blush was also acceptable. Gamble *et al*. (2006) also demonstrated a preference for intermediate-straight or elongate-concave shapes with green or yellow colours. Regarding preference of taste, Turner *et al*. (2005) indicated that consumers preferred a sweet pear with a strong pear flavour and Jaeger *et al*. (2003) also confirmed a general preference for juicy and sweet pears. Sensory traits that were found to be most important in pears were juiciness, sweetness, acidity, aroma, astringency, aftertaste, flesh texture and firmness (Kappel *et al*., 1995; Prederi *et al*., 2002). Results obtained can be used to verify the breeding objectives of the ARC pear breeding program are aligned with consumer preference for appearance and taste. The consistency of results with that of international studies also suggest that local consumers can be used to conduct preference studies on cultivars developed for the export market. This will be much cheaper than to conduct such studies in Europe, for example.

This research was performed on local residents who are all assumed to be South African. A suggested follow up on these results would be to perform a separate study with a sole focus on preference for appearance and making use of colour photographs of life-sized pears. This study would be focused on European citizens as this information would be very important to breeders for the export of pears. A follow up study to assess consumer preference for pear appearance and taste among different cultural groups in South Africa may also provide valuable data to cultivar developers and marketers. It is possible that the results of such a study may provide a different outcome from the data reported here since consumers from only cultural group were included in the present study.

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Table 4.1 Definition of sensory attributes for the sensory analysis of pear fruit. Source: Jaeger *et al*., 2003.

Attribute	Definition	Scale
Overall pear flavour	Aromatics of typical pear	0 = None 100 = Very strong pear flavour
Sweet taste	Basic taste on tongue caused by characteristic sugars	0 = None 100 = Prominent sweet taste
Sour taste	Basic taste on tongue caused by characteristic acids	0 = None 100 = Prominent sour taste
Crispness	Noise generated when first bite is taken with the front teeth	0 = None; 100 = Prominent crispness
Crunchiness	Noise generated when chewing with molars	0 = None 100 = Prominent crunchiness
Hardness	Force to required to compress sample with molars	0 = None 100 = Very hard
Melt character	Soft, melting of flesh in the mouth	0 = None 100 = Prominent meltiness
Juiciness	Amount of juice released by sample during chewing	0 = None 100 = Very juicy
Mealiness	Over-mature texture recognised by a soft dry pulp	0 = None 100 = Prominent mealiness
Grittiness	Presence of small hard particles in the flesh experienced between front teeth	0 = None 100 = Prominent grittiness

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Table 4.2 Degree of liking of appearance for pear genotypes measured on a nine point hedonic scale for total group as well as means of colour measurements of chroma, lightness and hue angles separated by LSD (5%).

Genotype	**Colour**	**Preference of appearance (N = 200)**	**Lightness (L*)**	**Chroma (C*)**	**Hue (hº)**
3D-44-3	Green	6.5 c	58.3 bcd	46.5 ab	109.8 a
Packham's Triumph	Green	6.8 b	62.8 ab	44.7 a	106.7 a
Concord	Green	5.7 d	62.1 b	48.4 a	106.0 a
4A-88-18	Green	4.2 g	61.8 bc	46.1 ab	105.0 ab
Bon Chrétien	Yellow	6.4 c	73.0 a	46.5 ab	93.8 bc
Abate Fetel	Green/Brown	4.7 ef	58.4 bcd	39.8 c	87.3 cd
Hosui	Brown	3.2 h	53.9 bcd	31.7 d	83.5 cd
Golden Russet Bosc	Brown	4.6 fg	51.6 cde	30.8 d	77.5 d
Rosemarie	Blush	7.5 a	50.4 de	43.0 bc	44.3 e
Cheeky	Blush	5.8 d	43.1 ef	43.0 bc	33.3 e
Red d'Anjou	Purple	4.9 e	36.8 f	22.4 e	33.1 e
LSD (p=0.05)		0.33	4.86	10.52	2.22
P-value		<0.0010	<0.0001	0.0012	<0.0001

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Table 4.3 Overall means of sensory characteristics measured on a 100 mm unstructured line scale during descriptive sensory analysis. Means separated by LSD (5%).

Genotype	Pear Flavour	Sour Taste	Sweet Taste	Hardness	Melt Character	Juiciness	Mealiness	Grittiness
3D-44-3	35.6 cd	17.0 f	44.9 bcd	22.5 c	30.6 c	31.4 cd	4.9 cd	12.2 cd
Packham's Triumph	27.8 e	32.5 ab	38.8 def	25.9 bc	17.1 ef	33.5 c	4.2 cd	7.8 ef
Concord	31.7 cde	20.8 ef	42.7 cde	29.3 b	9.7 fg	26.0 de	6.1 c	17.6 b
4A-88-18	29.1 de	20.7 ef	32.8 f	22.5 c	27.3 cd	37.2 bc	4.9 cd	15.9 bc
Bon Chrétien	60.3 a	29.2 abc	48.7 abc	6.6 e	74.5 a	58.6 a	11.0 b	9.1 def
Abate Fetel	35.1 cd	19.8 ef	42.6 cde	22.2 c	23.9 cde	42.8 b	4.2 cd	12.9 cd
Hosui	15.8 f	21.7 def	51.6 a	41.3 a	7.9 g	56.8 a	0.4 e	11.7 de
Golden Russet Bosc	37.1 c	26.9 cd	37.8 ef	15.9 d	21.0 de	31.0 cd	15.2 a	24.7 a
Rosemarie	50.9 b	33.7 a	42.6 cde	11.4 de	48.8 b	52.9 a	3.7 cde	7.5 ef
Cheeky	58.1 ab	24.3 cde	50.2 ab	14.0 d	41.3 b	54.1 a	1.9 de	7.5 f
Red d'Anjou	13.2 f	27.4 bc	21.2 g	44.3 a	4.38 g	20.6 e	3.3 cde	11.6 def
LSD (p=0.05)	7.32	5.29	6.13	6.22	8.47	6.54	3.62	4.18
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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Table 4.4 Overall means of physical measurements of firmness, sugar and acid content for each genotype as well as sugar and acid ratio. Means separated by LSD (5%).

Genotype	Firmness (kg)	TSS (ºBrix)	TA (% malic acid)	TSS/TA
3D-44-3	3.8 abc	14.7 ab	0.19 bcd	78.8 ab
Packham's Triumph	4.4 ab	15.2 a	0.29 a	55.3 bc
Concord	4.5 ab	14.2 ab	0.22 abc	70.0 bc
4A-88-18	2.8 abc	12.5 ab	0.21 bcd	64.2 bc
Bon Chrétien	1.5 c	13.1 ab	0.26 ab	51.3 c
Abate Fetel	3.3 abc	13.4 ab	0.14 d	98.4 a
Hosui	3.7 abc	14.1 ab	0.24 abc	62.5 bc
Golden Russet Bosc	3.4 abc	14.2 ab	0.25 abc	58.5 bc
Rosemarie	2.2 bc	12.3 b	0.25 abc	51.1 c
Cheeky	3.2 abc	13.8 ab	0.18 cd	76.9 ab
Red d'Anjou	5.0 a	12.5 ab	0.26 abc	49.5 c
LSD (p=0.05)	2.47	2.81	0.076	23.80
P-value	<0.0001	<0.0001	<0.0001	<0.0001

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Table 4.5 Overall degree of liking of taste measured on a nine point hedonic scale for the total group and male and female consumers. Means separated by LSD at 5%.

Genotype	**Preference of taste (N = 200)**
3D-44-3	4.9 d
Packham's Triumph	5.7 c
Concord	6.3 b
4A-88-18	5.0 d
Bon Chrétien	5.9 c
Abate Fetel	4.9 d
Hosui	4.7 d
Golden Russet Bosc	5.8 c
Rosemarie	6.8 a
Cheeky	6.7 a
Red d'Anjou	3.6 e
LSD (p=0.05)	0.38
P-value	<0.0001

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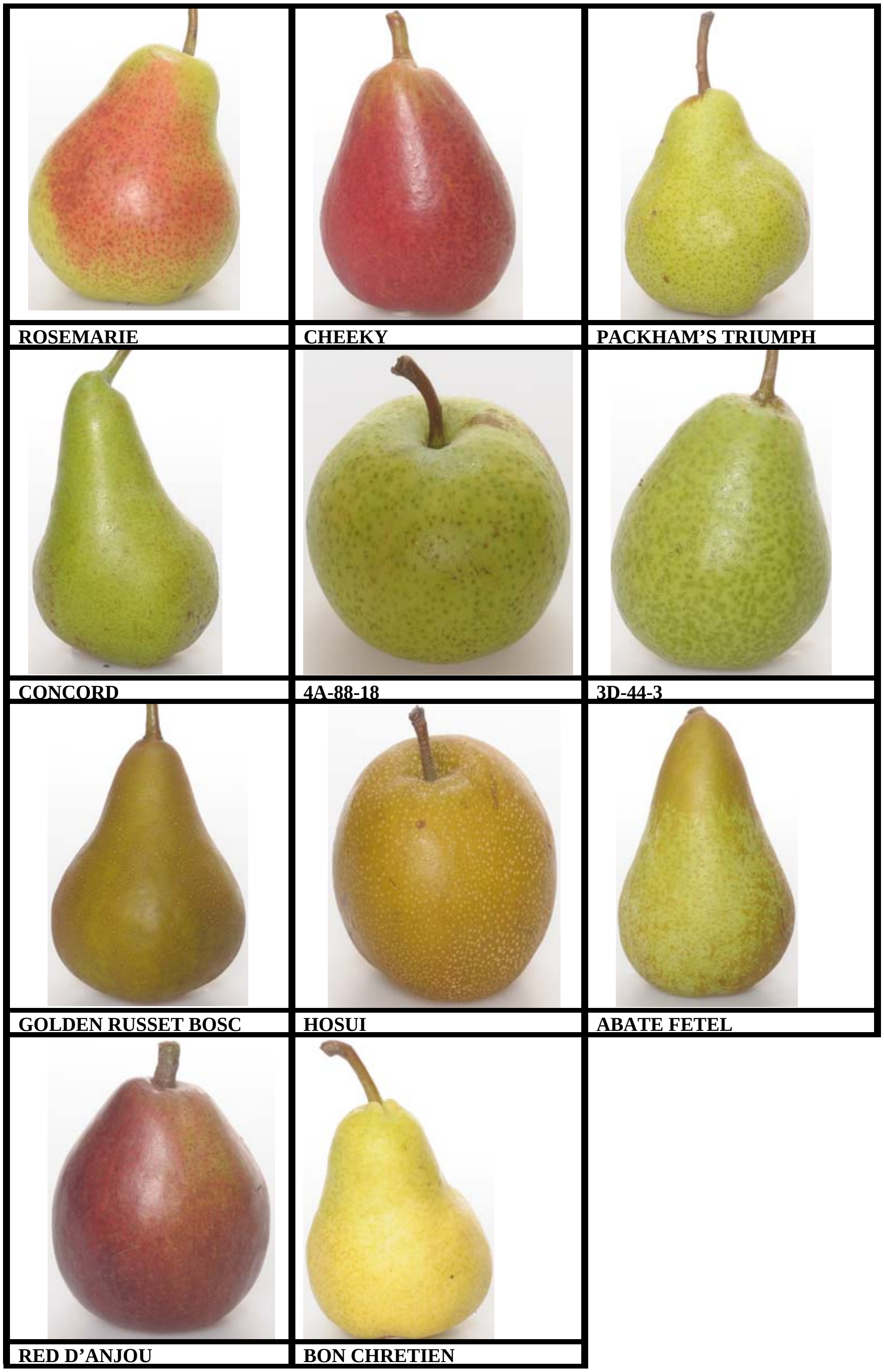

Figure 4.1 Photographs of a representative of each pear genotype used in the study taken after a minimum storage period of six weeks.

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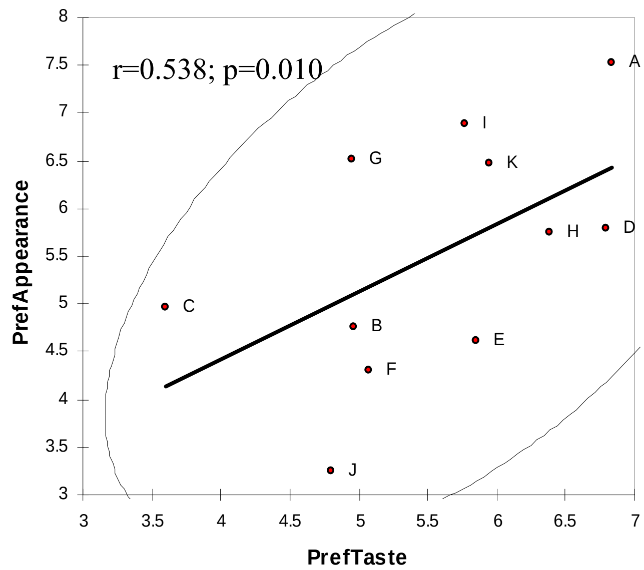

Figure 4.2 Scatter plot of overall means of both taste and appearance values by the total group of consumers. The pear genotypes were: Rosemarie (A); Abate Fetel (B); Red d'Anjou (C); Cheeky (D); Golden Russet Bosc (E); 4A-88-18 (F); 3D-44-3 (G); Concord (H); Packham's Triumph (I); Hosui (J); and Bon Chrétien (K). The values for preference were: 1 (dislike extremely); 2 (dislike very much); 3 (dislike moderately); 4 (dislike slightly); 5 (neither like nor dislike); 6 (like slightly); 7 (like moderately); 8 (dislike very much); 9 (dislike extremely).

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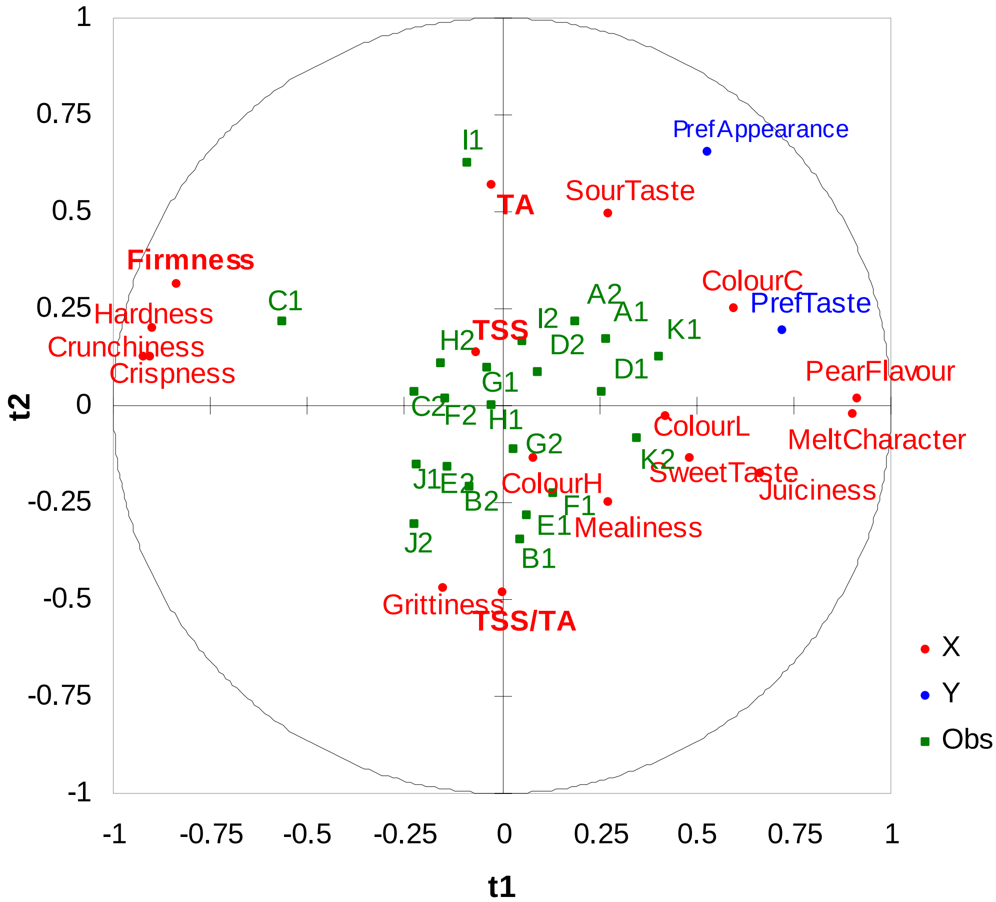

Figure 4.3 External preference map with maturity indicators, indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the ten sensory attributes. The pear genotypes were: Rosemarie (A); Abate Fetel (B); Red d'Anjou (C); Cheeky (D); Golden Russet Bosc (E); 4A-88-18 (F); 3D-44-3 (G); Concord (H); Packham's Triumph (I); Hosui (J); and Bon Chrétien (K). The consumer results were: Preference of appearance (PrefAppearance) and preference of taste (PrefTaste). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the trained panel and instrumental data (x space).

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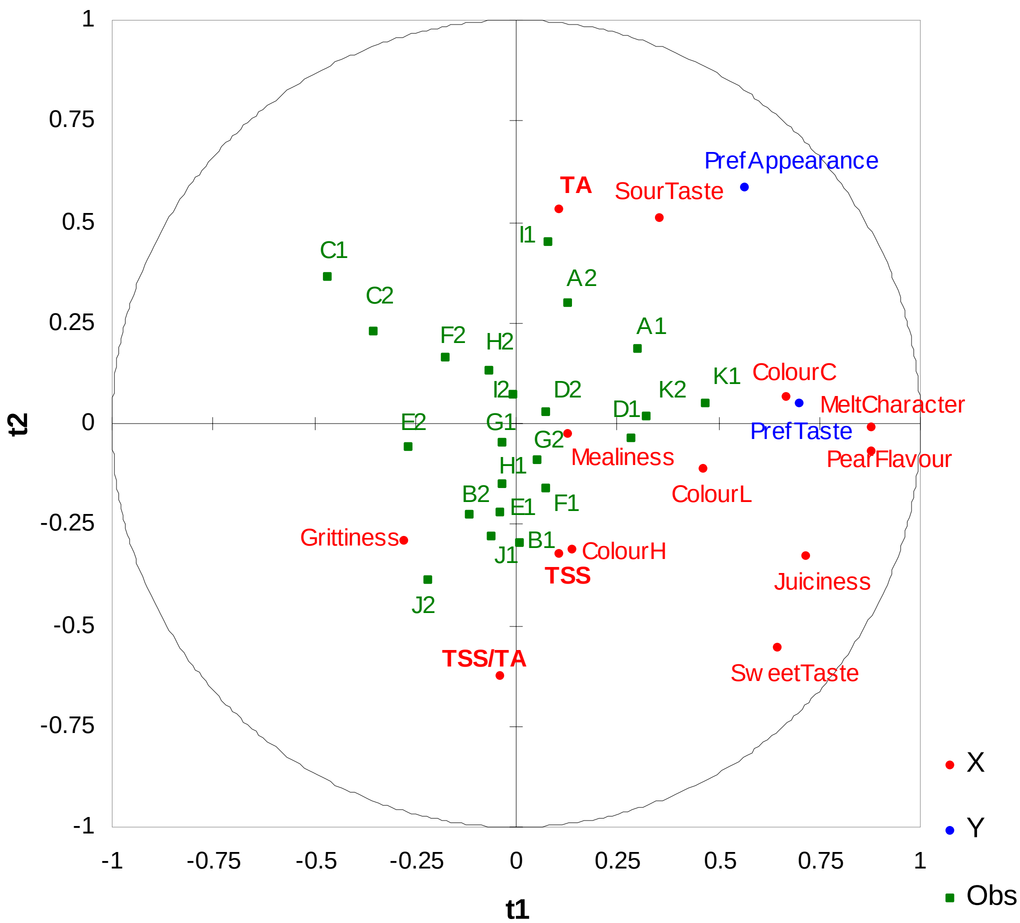

Figure 4.4 External preference map without maturity indicators, indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the ten sensory attributes. The pear genotypes were: Rosemarie (A); Abate Fetel (B); Red d'Anjou (C); Cheeky (D); Golden Russet Bosc (E); 4A-88-18 (F); 3D-44-3 (G); Concord (H); Packham's Triumph (I); Hosui (J); and Bon Chrétien (K). The consumer results were: Preference of appearance (PrefAppearance) and preference of taste (PrefTaste). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the trained panel and instrumental data (x space).

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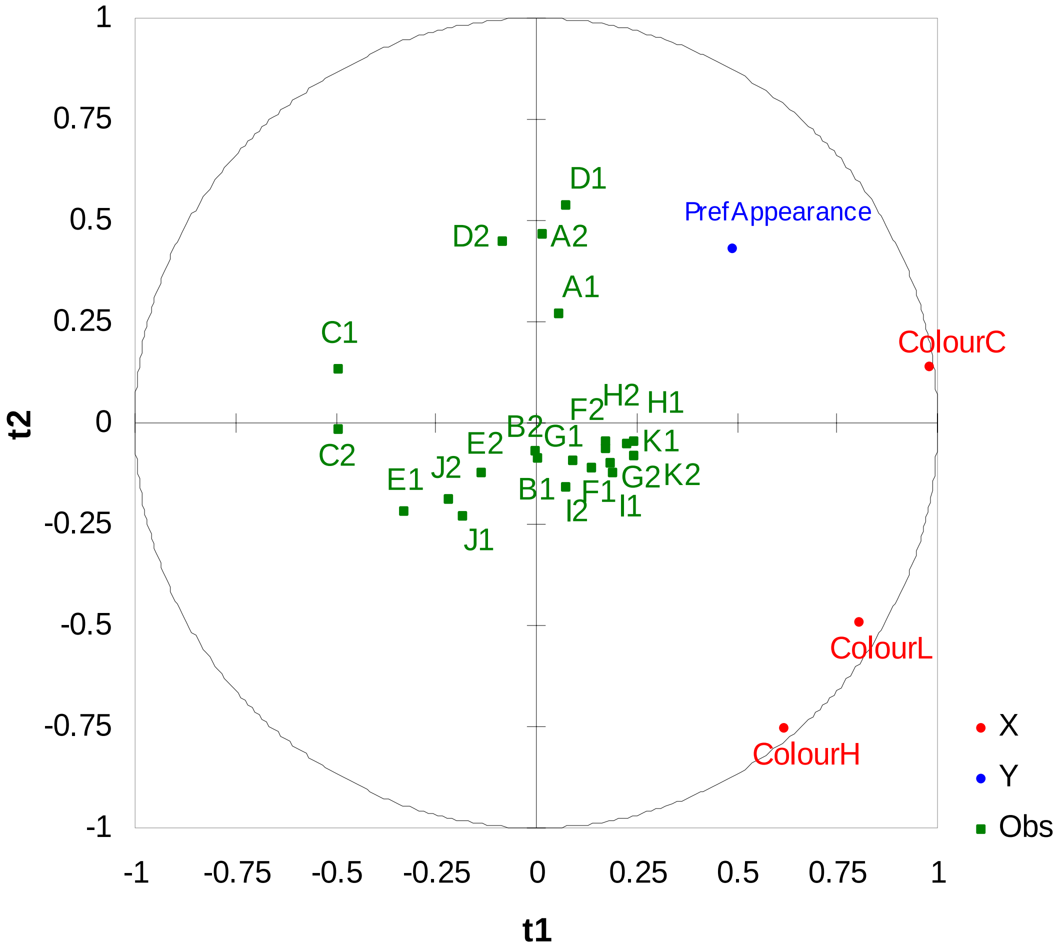

Figure 4.5 External preference map indicating the position of the consumers in relation to the eleven pear genotypes (capital letters) and the instrumental colour measurements. The pear genotypes were: Rosemarie (A); Abate Fetel (B); Red d'Anjou (C); Cheeky (D); Golden Russet Bosc (E); 4A-88-18 (F); 3D-44-3 (G); Concord (H); Packham's Triumph (I); Hosui (J); and Bon Chrétien (K). The consumer results were: Preference of appearance (PrefAppearance). The map was obtained using a partial least square regression, where the consumer data (y space) was regressed onto the instrumental data (x space).

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CHAPTER 5

Preference and ideal pear appearance among European consumers using colour images

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ABSTRACT

The pear industry in South Africa exports more than one third of their total crop. From this amount more than 80% is exported to the European Union and the United Kingdom. Therefore, it is important to understand the needs of these consumers in order to stay competitive on overseas markets. The research in this section was exclusively on European pear consumers. Photographs of different pear cultivars of varying colours and shapes were shown to 60 pear consumers currently living in or originally from a European country. Ten European countries were represented but these were divided into two categories, namely Great Britain and Europe. The degree of liking of colour and overall appearance and their willingness to pay for the pears was asked, as well as general questions regarding their ideal pear.

Preference was for the green, yellow and light blush colours for both groups, although Great Britain generally awarded higher values. The same results were seen for the degree of liking of overall appearance with only pears that had a round or elongate shape decreasing in preference. There was a strong positive correlation between the colour liking and the overall appearance. There was also a strong positive correlation between the willingness to pay and degree of liking of colour, as well as with the degree of liking of appearance. In conclusion, the European market is looking for a bright yellow, green or light blush, pyriform or ‘pear shaped’ pear.

Key words: *Pyrus communis*, photographs, preference, shape

INTRODUCTION

South Africa exports approximately 38% of the total pear production of approximately 347,763 tons (DFPT, 2008). Export volumes have almost doubled over the last decade (Ferrandi *et al*., 2005), stressing the importance of the overseas market. Continental Europe accounts for about 61% of the exports and the United Kingdom for about 20% (DFPT, 2008). In order to increase the market share of South African pears in the European market, the pear breeding programme of the Agricultural Research Council (ARC) aims to breed new cultivars that are preferred by consumers with regard to appearance and taste (Human, 2005).

A consumer will probably use appearance to explain their choice of a certain food product over another (Jaeger *et al*., 2003). In fruit, a cultivar could be purchased with which

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the consumer has previous experience but if not, appearance together with aroma and physical cues, are the only sensory attributes that can be used to form a decision (Jaeger *et al*., 2003). Regarding appearance, the colour of the pear skin is very important to consumers. They find that the colour of the pear can help them in assessing the quality and maturity. Consumers are willing to pay higher amounts for an attractive fruit (Human, 2005).

A few studies have been done on the appearance analysis of pears based on colour and shape. Kappel *et al*. (1995) found that Canadian consumers had a preference for yellow skin or even a slight red blush was acceptable. A pyriform shape was preferred. In the study by Gamble *et al*. (2006), New Zealand and Australian consumers showed a preference for green or yellow colours and intermediate-straight or elongate-concave shapes. In previous research (Chapter 3 and 4), the most important factors for South African consumers influencing their choice of a pear was asked. The results showed that these consumers would choose a green and red or a yellow and red skin colour. These preferences most likely correspond with the colour of pears that the consumers are familiar with (Jaeger *et al*., 2003).

In Europe, the green russeted 'Conference' has become the most important pear cultivar; it comprises 25% of the total production, followed by the yellow (sometimes with a light red blush) 'Williams Bon Chrétien' with 11% and the green russeted and elongated 'Abate Fetel' with 10% (Deckers and Schoofs, 2005). Doyenné du Comice (green but sometimes with a light red blush) is another important cultivar that has long been available in the European market (Vaysse *et al*., 2005). Since European consumers are familiar with these cultivars, we presume that yellow, green and a light blush would be the preferred skin colours. Since there seems to be a high demand for red blushed cultivars (Human, 2005), the breeding of these cultivars is a major objective of the ARC breeding programme (Human, 2007).

Research was performed by using 16 digital photographs of existing pears and three pears that have had the skin colour manipulated. The aim of this research is to determine the preference of the appearance of pears by European consumers. They were also asked to answer a number of questions regarding their preference of the colour, shape, willingness-to-pay, and expected taste of the pears. This study allows us to create an understanding of what the ideal pear for the European market is.

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MATERIALS AND METHODS

Pear images

Sixteen pear photographs were chosen to represent the range of pear colours and shapes available for the European market. Red, yellow, green, brown (russet or a degree of russet colouring) and differing degrees of blush colours were present and round and pyriform or elongated pyriform shapes were chosen to represent the different forms obtainable. The pears were first individually photographed, after they had been in storage for a minimum of six weeks, and digitally stored on the computer. Fourteen of these pears are existing cultivars, namely, Ya (*P. bretschneideri* Redh.) (light yellow, round), Concord (green, elongated pyriform), Abate Fetel (green and brown russet, elongated), Conference (green with brown russeted markings, elongated pyriform), Bosc (brown russet, pyriform), Golden Russet Bosc (golden brown, pyriform), Williams Bon Chrétien (yellow, pyriform), Rosemarie (red blush on yellow or pink blush on yellow, pyriform), Flamingo (red blush on yellow, pyriform), Forelle (red blush, round, pyriform), Cheeky (bright red, elongated round), Red d'Anjou (dark red, round) and Bon Rouge (purple, round pyriform with uneven surface). The remaining two are the shape of the existing cultivar but the skin colour was manipulated using Adobe Photoshop (CS3 v.10.0.1; 1990-2007 Adobe systems Incorporated, Chicago, USA). These were a 'Red d'Anjou' shape with a striped red overlay colouring of a 'Royal Gala' apple and a 'Cheeky' shape with a pink colouring. The computer programme, Adobe Photoshop, was used to transfer the skin colour from one image onto the newly created pear image or the skin colour of the original pear was digitally enhanced. Each pear image had the same white background as for this factor to not have an effect on the colour perception of the pears. Once the images were ready for printing, they were printed as standard size (10cm x 15cm), matte photographs. The sequence was randomly selected, marked from 'A' to 'P' and bound with a ring-binder along the left hand border. The images of these pear photographs are shown in Figure 5.1. This was similar to the images created by Gamble *et al*. (2006) in the study to determine preference of appearance among Australian and New Zealand consumers.

Questionnaires

The consumers were given a questionnaire with four subsections: Q1, Q2, Q3 and Q4. A nine-point hedonic scale was used to rate the degree of liking of the colour (Q1) and the overall appearance (Q2) of the pear images (Fig. 5.1). The willingness-to-pay for each pear was asked on a scale from one to three (below average, average or above average) on Q3. The last section (Q4) was general queries on the taste and appearance attributes of their ideal

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pear as well as the cultivar or colour pear they would normally purchase. Any consumer that completed the questionnaire received a bottle of wine (Avondrood Vineyards; Sauvignon Blanc or Chardonnay) as a gesture of appreciation.

Participants

The total of 60 consumers was sourced from a number of different situations. Originally, a local guesthouse, in Stellenbosch, South Africa, that is well-known as accommodation for tourists, was approached. It was agreed that any European tourists that would stay there during this time would be asked to fill in the questionnaire and receive their bottle of wine. When this study was performed it was not the time of year when many Europeans visit South Africa and other sources had to be used to recruit enough participants. Local residents that were of European origin were also approached to participate. These consumers reside in South Africa for the summer months and return to Europe during the winter. All international students at the University of Stellenbosch, South Africa, were approached via e-mail to participate. The final means of recruitment was a website (www.manning.co.za/pears) that was structured with the questionnaire in both English and a translation in German and all the clearly marked pear images. In this way, the participants could answer all the necessary questions by filling in the appropriate areas even if they are situated in Europe.

Colour

The colour of each photograph was objectively measured using a handheld colorimeter (Nippon Denshoku Model HR-3000, Tokyo, Japan) placed at approximately the mid point between the calyx and the stem or on the reddest position for pears with a red colouring. The chroma (C), lightness (L) and hue angles (0º = red-purple, 90º = yellow and 180º = bluish-green) were measured. Colour increase in brightness and lightness with an increase in the C and L values from 0 to 100.

Statistical procedures

The data was subjected to an appropriate analysis of variance (ANOVA) on 60 judges and 16 products on a nine point hedonic scale using SAS statistical software (SAS, Version 9, 1999, Cary, North Carolina). Shapiro-Wilk's test was performed on the standardised residuals to test for non-normality (Shapiro and Wilk, 1965). In the cases of significant evidence against normality, which was due to skewness, outliers were identified and removed until the residuals were symmetric or significantly normal (Glass *et al*., 1972). Means were compared

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with Student's t-LSD (Least Significant Difference) at a 5% significance level. Pearson's correlation between attributes and consumer preferences and a PCA (Principle Component Analysis) was performed using XLStat (Addinsoft, Version 2007, Paris, France).

RESULTS AND DISCUSSION

Consumer demographics

The 60 consumers that took part in the study originated from ten different countries. The breakdown of these countries is shown in Table 5.1. These countries were subsequently divided into two groups, namely continental Europe and Great Britain for statistical reasons. The females dominated over the male consumers by 73% to 27%. The majority (52%) consume pears twice a month and there were no participants that do not consume pears at all. There was a fairly even age distribution among the consumers, the majority were older than 60 (28%) and the smallest age group was between 40 and 49 (15%).

Colour

'Concord' is the only genotype with a hue angle of 100 (Table 5.2). This is also the only full green pear. The genotypes with hue angles between 74 and 97 have a brown or yellow colouring. 'Abate Fetel' and 'Conference' are green pears with brown markings or russeting. Genotypes with a hue slightly lower than this (ranging from 42 to 28) have a light red colouring or red/pink blush. 'Red d'Anjou' is a dark red pear and has a low hue of 27 and pears lower than this are very dark red colours such as 'Cheeky' and, the lowest hue of 'Bon Rouge' (14.6). The lightness and chroma values follow similar patterns for the genotypes. 'Bon Chretien' has the highest lightness and chroma which would mean that this is the brightest pear of all. 'Bon Rouge' has the lowest values for both lightness and chroma. This pear is therefore the least bright and has the dullest complexion. 'Cheeky' and especially the simulated 'Cheeky' has a similar hue angle to 'Bon Rouge' but the lightness and chroma is much higher. This may effect the overall preference. The red and pink 'Rosemaries', 'Forelle' and 'Golden Russet Bosch' also have relatively a high chroma, the rest are below 41.

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Preference of colour

There was significant interaction between country group and pear genotype for the overall degree of liking of colour. The overall means for the country groups are shown in Table 5.3.

‘Concord’ and ‘Bon Chretien’ were the more preferred genotypes for continental Europe apart from ‘Abate Fetel’, the pink ‘Rosemarie’ and the red ‘Rosemarie’. These genotypes were all rated over 6.0, i.e., a positive liking. ‘Flamingo’ was rated slightly lower but not significantly different to the latter three genotypes mentioned. The simulated ‘Cheeky’, ‘Cheeky’, ‘Flamingo’, ‘Forelle’ and ‘Conference’ were also all in the neutral degree of liking group and were not rated significantly lower than ‘Flamingo’. ‘Golden Russet Bosc’ was rated only slightly lower (not significantly) than this with 4.9. The simulated ‘Red d’Anjou’, ‘Bosc’, ‘Ya’ and ‘Red d’Anjou’ were also scored in this degree of liking category, i.e., dislike slightly. The least preferred genotype overall was ‘Bon Rouge’ but its rating was not significantly lower than that of ‘Bosc’, ‘Ya’ and ‘Red d’Anjou’.

The Europe group therefore preferred green, yellow, light blush, and a green and light brown combination of colours. An increase in red colour as well as an increase of brown colouring or russeting decreased the preference. The study done by Gamble *et al*. (2006) also showed that consumers avoided the russeted pears when they were presented with pear images. The reason for ‘Abate Fetel’ having a high degree of liking even though it does contain a degree of russeting, could be because the consumers are familiar with this cultivar or the russeting is very light and situated mainly at the tip of the pear thereby increasing its preference.

The variation between genotypes for Great Britain was much less. This group had the highest preference for ‘Concord’ but not significantly different from the pink ‘Rosemarie’, ‘Bon Chretien’, ‘Forelle’, ‘Cheeky’, the simulated ‘Cheeky’, the red ‘Rosemarie’, ‘Flamingo’, ‘Abate Fetel’ and the simulated ‘Red d’Anjou’. All these genotypes were scored above 6.0 and therefore had a positive degree of liking. ‘Bosc’ was significantly different from this group but was placed in the neutral degree of liking category. ‘Golden Russet Bosc’ and ‘Red d’Anjou’ was rated only slightly lower and also not significantly different from all these genotypes apart from ‘Concord’ and the pink ‘Rosemarie’. The lowest preference was for ‘Ya’ but was not significantly lower than for ‘Bon Rouge’ and ‘Conference’. There were no distinct groups of preference, although, it does seem that green was most preferred as well as light red or pink blush, yellow, or green and light brown combination. Brown or russet colours did not receive a negative liking. The only colours which were below 5.0 were dark

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red or purple ('Bon Rouge'), the light yellow colour of 'Ya' and green with brown markings ('Conference').

Similarities did exist between the two country groups. Both groups had the highest preference over all the genotypes for the green pear, 'Concord' and both groups disliked 'Bon Rouge' and 'Ya'. Great Britain gave higher scores, in general, with the exception of only three genotypes but the difference was minor. The largest difference between the genotypes that Great Britain awarded higher ratings for was the dark red, 'Red d'Anjou'. Other substantial differences were for the blushed cultivars Forelle, the dark red Cheeky, the brown Bosc and the simulated Red 'd Anjou. A comparison made by Gamble *et al*. (2006) between New Zealand and Australian consumers showed that Australians have a higher preference for the red coloured pears. This could indicate differences in the pears that these consumer groups are familiar with. A large portion of South African exports to continental Europe and Great Brittain consist of 'Forelle' (17.5%), 'Williams Bon Chretien' (15.2%), 'Beurre Bosc' (4.8%) and 'Rosemarie' (2.4%) (DFPT, 2008) included in this study. It appears that these red and brown coloured pears may be favoured more in the United Kingdom than Europe. Interestingly, the genotypes that are more prevalent in Europe, i.e., 'Conference', 'Williams Bon Chretien' and 'Abate Fetel', did score slightly higher, although not statistically significant, than in Great Britain.

Preference of appearance

There was significant interaction between country group and genotype for the overall degree of liking of appearance. The means for the country groups are shown in Table 5.4.

The Europe group again has the highest preference for 'Concord' although it was not significantly higher than 'Bon Chretien' and the red 'Rosemarie'. The pink 'Rosemarie' also received a high degree of liking and its score was not significantly lower than the latter two genotypes. 'Abate Fetel' and 'Flamingo' were both rated slightly lower (not significantly lower than the pink 'Rosemarie') but still above 6.0. The simulated 'Cheeky', 'Golden Russet Bosc', 'Cheeky', 'Conference', 'Bosc' and 'Forelle' all had a neutral degree of liking with no significant difference in rating. The simulated 'Red d'Anjou' and 'Bon Rouge' received a negative degree of liking and 'Bon Rouge' did not differ significantly in rating from the genotypes with the lowest preference, 'Red d'Anjou' and 'Ya'. Most of the pears increased in liking when the preference of overall appearance was asked. The greatest increase was with the red 'Rosemarie'. The darker red blush may have been unfavourable and the typical pear shape would increase the degree of liking. The few pears that did

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decrease in liking for appearance were all round shapes (‘Red d’Anjou’, ‘Forelle’ and ‘Ya’) or an elongated shape (‘Abate Fetel’). The least preferred pears in the studies done by Gamble *et al*. (2006) and Kappel *et al*. (1995) were also red and round shaped pears. The greatest decrease was the ‘Ya’ genotype which has a roundish shape and a light yellow colour.

‘Concord’ was the more preferred genotype for Great Britain, but its rating was not significantly higher than ‘Bon Chretien’, the red ‘Rosemarie’, the pink ‘Rosemarie’, ‘Flamingo’, ‘Bosc’, the simulated ‘Cheeky’ and ‘Golden Russet Bosc’. ‘Abate Fetel’ and ‘Cheeky’ also received positive ratings and did not differ significantly from all these genotypes apart from ‘Concord’. The simulated ‘Red d‘Anjou’, ‘Bon Rouge’, ‘Forelle’, ‘Red d’Anjou’ and ‘Conference’ were all in the neutral degree of liking category. ‘Ya’ was the genotype with the lowest preference but not significantly different to ‘Conference’ and ‘Red d’Anjou’. Most of the pears also increased in liking when the preference of overall appearance was asked to the Great Britain group. The greatest increase was for ‘Bosc’. This is a very russeted brown pear with a typical pear shape which would increase its overall preference. The red ‘Rosemarie’ and ‘Golden Russet Bosc’ also increased in liking for overall appearance. These pears are also both typical pear shapes and again, the red ‘Rosemarie’ had a favourable degree of liking for colour but increased even more with appearance. ‘Golden Russet Bosc’ had a slight negative liking for colour which increased to neutral for appearance. The greatest decrease in liking was found with ‘Forelle’. This pear’s blush colour was highly preferred but its atypical shape decreased the degree of liking. Jaeger *et al*. (2003) and Gamble *et al.* (2006) also found that consumers had a liking of pyriform, or typical pear shapes, rather than round shapes.

The main difference between the results from the two groups is that Great Britain generally awarded higher scores. Of the few genotypes Great Britain had a lower degree of liking for, ‘Conference’ showed the greatest difference but this was not significant. The greatest increase in liking was mostly with the round shaped and red or brown coloured genotypes (‘Red d’Anjou’, simulated ‘Red d’ Anjou’, ‘Bon Rouge’, simulated ‘Cheeky’ and ‘Bosc’).

Correlations

The scatter plots in Figure 5.2 show the degree of liking of colour against the degree of liking of appearance for the Europe and Great Britain groups. Both these groups show a strong

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positive correlation (r=0.962; r<0.001; r=0.795; p=0.001, respectively). Therefore, the higher the liking for colour is, the higher the liking for the overall appearance (Imram, 1999).

Both graphs show clear subsections as well as similarities and differences between the two groups. Europe has a top group of 'Concord', 'Bon Chretien', the red 'Rosemarie', the pink 'Rosemarie' and 'Abate Fetel'. The middle group with a moderate liking include 'Flamingo', the simulated 'Cheeky', 'Conference', 'Forelle', Golden Russet Bosc', 'Bosc' and the simulated 'Red d'Anjou'. The least preferred pears were 'Bon Rouge', 'Red d'Anjou' and 'Ya'.

Great Britain had a larger top group of genotypes. Within this group, the highest overall was 'Concord', 'Bon Chretien', the pink 'Rosemarie' and the red 'Rosemarie'. This is similar to Europe, apart from 'Abate Fetel'. 'Abate Fetel' is widely available in Europe which may cause the higher preference, due to familiarity, in this region. 'Flamingo', the simulated 'Cheeky', 'Cheeky', 'Abate Fetel', the simulated 'Red d'Anjou' and 'Forelle' also form the top group of genotypes. This includes all the bright red and blushed varieties and the green and brown 'Abate Fetel'. The middle group is formed by only the two brown genotypes 'Bosc' and 'Golden Russet Bosc' and the full red 'Red d'Anjou'. The former two have a favourable shape but the round shape of 'Red d'Anjou' was not as popular. 'Bon Rouge' and 'Conference' did not have a high degree of liking and 'Ya' the least. These three genotypes form the lowest preference group. This is similar to Europe apart from 'Conference' having a higher preference for Europe. This could also due to the wider availability and familiarity of this genotype. The red genotype 'Red d'Anjou' had a higher preference with Great Britain than Europe.

The degree of liking of colour with the willingness to pay and the degree of liking of appearance and the willingness to pay showed high positive correlations for both groups. The correlations between willingness to pay and degree of liking of colour and appearance for Europe were slightly higher (r=0.956; p<0.001 and r=0.935; p<0.001, respectively). The correlations between willingness to pay and degree of liking of colour for Great Britain was slightly lower than for degree of liking of appearance (r=0.791; p=0.001 and r=0.909; p<0.001, respectively). In both groups, the more the consumers prefer the colour or appearance, the more they would be willing to pay for the pear. Both groups show a fair amount of variation within the willingness to pay categories, especially Great Britain. There seems to be less variation among the cultivars that received the highest ratings and with those that received the lowest ratings. The variation is greatest with the genotypes that received

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average values. The consumers could not clearly define if they would be willing to pay an average amount or a below average amount for these pears.

A separate correlation was performed between the instrumental colour measurements and the overall degree of liking (for both groups together) of colour and appearance and the willingness to pay results. The only colour measurement showing a significant correlation with the consumer's preference values was chroma. The correlations were similar: degree of colour liking ($r=0.635$; $p<0.001$), degree of appearance liking ($r=0.609$; $p<0.001$) and willingness to pay ($r=0.661$; $p<0.001$). The consumers therefore preferred a brightly coloured pear. It has been found through other studies that brighter coloured fruit is preferred by consumers over fruit that has a duller complexion (Sanderson, 2007; Baarschers, 1996). This can be illustrated by 'Cheeky' which had comparable lightness and hue angles to 'Red d'Anjou' and 'Bon Rouge' but the chroma value was much higher (Table 5.2). 'Cheeky' had a significantly higher degree of liking of colour than 'Red d'Anjou' and 'Bon Rouge'.

General questions

The answers given by the consumers on the second section of the questionnaire showed the same trend as the results from the first section. The two groups showed similar results for the general questions and no large differences were apparent, the answers are therefore discussed for the overall group. Consumers indicated that their ideal taste or texture was juicy (28%), sweet (23%), strong pear flavour (14%), or a soft texture (13%). This was similar to the previous studies performed on South African consumers (Chapter 3 and 4). Juicy, sweet, pear flavour and a soft texture were also important to them but the South African consumers emphasised that the texture must not be mealy. The ideal appearance agreed with the results from the photographs. Pear shape was the most important attribute with 21%; a yellow colour (18%) followed by green (17%), blush (17%) and red (14%) was most preferred. The majority of the consumers (81%) were not sure what the names of the cultivars were that they usually purchase. The South African consumers were also not aware of cultivar names. The few cultivar names that were indicated were Bon Chrétien (8%) and Forelle (6%). The colour pears that were usually purchased were green (33%), blushed (27%) and yellow (16%).

CONCLUSIONS

Colour proved to be the most important factor for European consumers when judging the appearance of the pear photographs. Yet, shape also had an effect. When the shape of the

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pear was round or what one would not associate with a typical pear shape, it was marked lower for the degree of liking of the overall appearance than for colour. Overall, green, yellow and light blush colours were preferred. This concurs with the results from Gamble *et al*. (2006) who found that green or yellow colours were the preference among Australian and New Zealand consumers. Kappel *et al*. (1995) also found that the preference was for yellow and blush colours with the research done on Canadian consumers. The research done previously on local pear consumers (Chapter 4) also resulted in the highest preference for a blush skin colour but green and yellow colours also received a high degree of liking. However, in study using pictures of apples by Jaeger and MacFie (2001), it was found that the analysis of the picture by the consumer is likely to depend on the colour they would normally consume. It was also clear that brighter colours were preferred over dull or darker colours. Both the simulated pear colours received higher preference ratings for colour and overall appearance than their original pear cultivar. The colours that were simulated were both brighter and lighter than the original.

The general questions asked to the consumers also proved that green, yellow and blush colours were most preferred. A red colour was also answered a number of times. This does not agree with the overall results from the photographs but the Great Britain group seemed to have a higher preference for the red coloured pears than the Europe group. The answers given by Great Britain could be the reason for red being one of the preferred colours.

In conclusion, the European market is looking for a bright yellow, green or light blush, pyriform or 'pear shaped' pear. These results show that consumers preferred pears that they could recognize and were familiar with. These types of pears could be attractive to those who consume pears regularly but there is not much to distinguish them visually from other similar, existing pears and thereby creating a challenge for marketers. A new pear should have a good pear flavour, be intermediate-straight or elongate concave, with a distinctly different colour from current pears to ensure cultivar/brand recognition in the market (Gamble *et al*., 2006).

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Table 5.1 European countries from which the participating consumers originate from and the country group they were divided into.

Country	**Number of consumers**	**Percentage (%)**	**Country Group**
Germany	21	35	Europe
England	18	30	Great Britain
Holland	6	10	Europe
Belgium	5	8	Europe
France	2	3	Europe
Italy	2	3	Europe
Switzerland	2	3	Europe
Wales	2	3	Great Britain
Ireland	1	2	Great Britain
Scotland	1	2	Great Britain
Total	60	100	

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Table 5.2 Colour measurements of chroma, lightness and hue angles of each photograph taken at the mid point of the pear image or on the reddest position for red coloured pears. Measurement are for one photograph per cultivar.

Cultivar	**Colour**	**Lightness**	**Chroma**	**Hue (º)**
Concord	Green	67.4	39.1	100.0
Abate Fetel	Green & Brown	70.2	39.8	96.8
Conference	Green & Brown	58.3	40.2	89.0
Bon Chrétien	Yellow	78.5	52.6	86.7
Bosc	Brown	52.2	32.0	81.6
Ya	Light yellow	64.2	32.0	79.9
Golden Russet Bosc	Golden brown	56.8	44.8	74.6
Rosemarie (red)	Blush	50.3	47.5	41.3
Red d'Anjou (simulated)	Red	48.2	40.1	40.5
Rosemarie (pink)	Blush	53.7	45.0	35.5
Flamingo	Blush	40.7	39.5	33.4
Forelle	Blush	40.5	45.2	27.6
Red d'Anjou	Red	42.8	22.7	27.1
Cheeky	Red	44.6	43.9	25.4
Cheeky (simulated)	Red	47.9	42.1	16.3
Bon Rouge	Purple	35.1	21.8	14.6

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Table 5.3 Overall means for degree of liking of colour measured on a nine point hedonic scale for the two country groups. Means separated by LSD (5%).

Cultivar	Colour	Europe (N = 38)	Great Britain (N = 22)	P-value
Concord	Green	7.1 a	7.1 a	0.9919
Abate Fetel	Green & Brown	6.6 ab	6.3 abcd	0.5298
Conference	Green & Brown	5.3 cde	4.7 ef	0.4827
Bon Chrétien	Yellow	6.9 a	6.7 abc	0.6354
Bosc	Brown	4.5 efg	5.8 bcde	0.0148
Ya	Light yellow	4.1 fg	4.3 f	0.7194
Golden Russet Bosc	Golden brown	4.9 cdef	5.6 cde	0.1574
Rosemarie (red)	Blush	6.4 ab	6.5 abcd	0.8935
Red d'Anjou (simulated)	Red	4.8 def	6.1 abcd	0.0166
Rosemarie (pink)	Blush	6.5 ab	6.8 ab	0.4800
Flamingo	Blush	5.7 bc	6.4 abcd	0.1605
Forelle	Blush	5.3 cde	6.6 abcd	0.0095
Red d'Anjou	Red	4.1 fg	5.6 cde	0.0033
Cheeky	Red	5.3 cde	6.6 abcd	0.0048
Cheeky (simulated)	Red	5.4 cd	6.5 abcd	0.0233
Bon Rouge	Purple	3.9 g	4.8 ef	0.2087
LSD (p=0.05)		0.87	1.09	
P-value		<0.0001	<0.0001	

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Table 5.4 Overall means for degree of liking of appearance measured on a nine point hedonic scale for total group and two country groups. Means separated by LSD (5%).

Cultivar	Colour	Europe (N=38)	Great Britain (N=22)	P- value
Concord	Green	7.6 a	7.3 a	0.4663
Abate Fetel	Green & Brown	6.4 c	6.2 bcd	0.6819
Conference	Green & Brown	5.3 def	5.0 ef	0.5184
Bon Chrétien	Yellow	7.4 ab	7.2 ab	0.6127
Bosc	Brown	5.2 ef	6.9 ab	0.0020
Ya	Light yellow	3.5 h	4 0 f	0.4066
Golden Russet Bosc	Golden brown	5.5 de	6.3 abc	0.1255
Rosemarie (red)	Blush	7.3 ab	7.2 ab	0.8601
Red d'Anjou (simulated)	Red	4.6 fg	5.6 cde	0.0054
Rosemarie (pink)	Blush	6.7 bc	6.9 ab	0.6587
Flamingo	Blush	6.0 cd	6.9 ab	0.0670
Forelle	Blush	5.1 ef	5.3 cde	0.7207
Red d'Anjou	Red	3.7 h	5.1 def	0.0054
Cheeky	Red	5.4 def	6.2 bcd	0.0920
Cheeky (simulated)	Red	5.5 de	6.7 ab	0.0233
Bon Rouge	Purple	4.0 gh	5.4 cde	0.0199
LSD (p=0.05)		0.80	1.10	
P-value		<0.0001	<0.0001	

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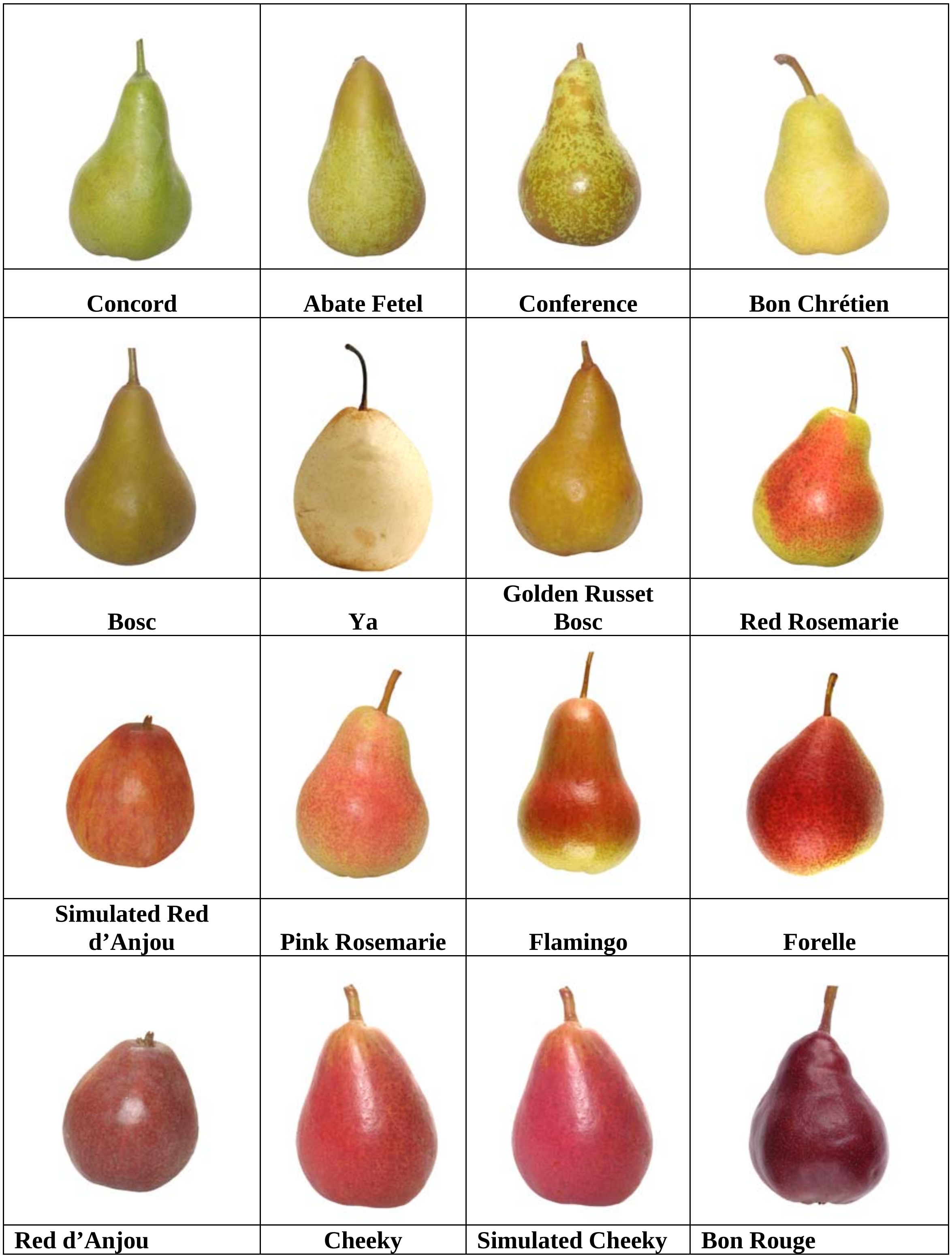

Figure 5.1 Images of each pear photograph used in the study taken after a storage period of six weeks.

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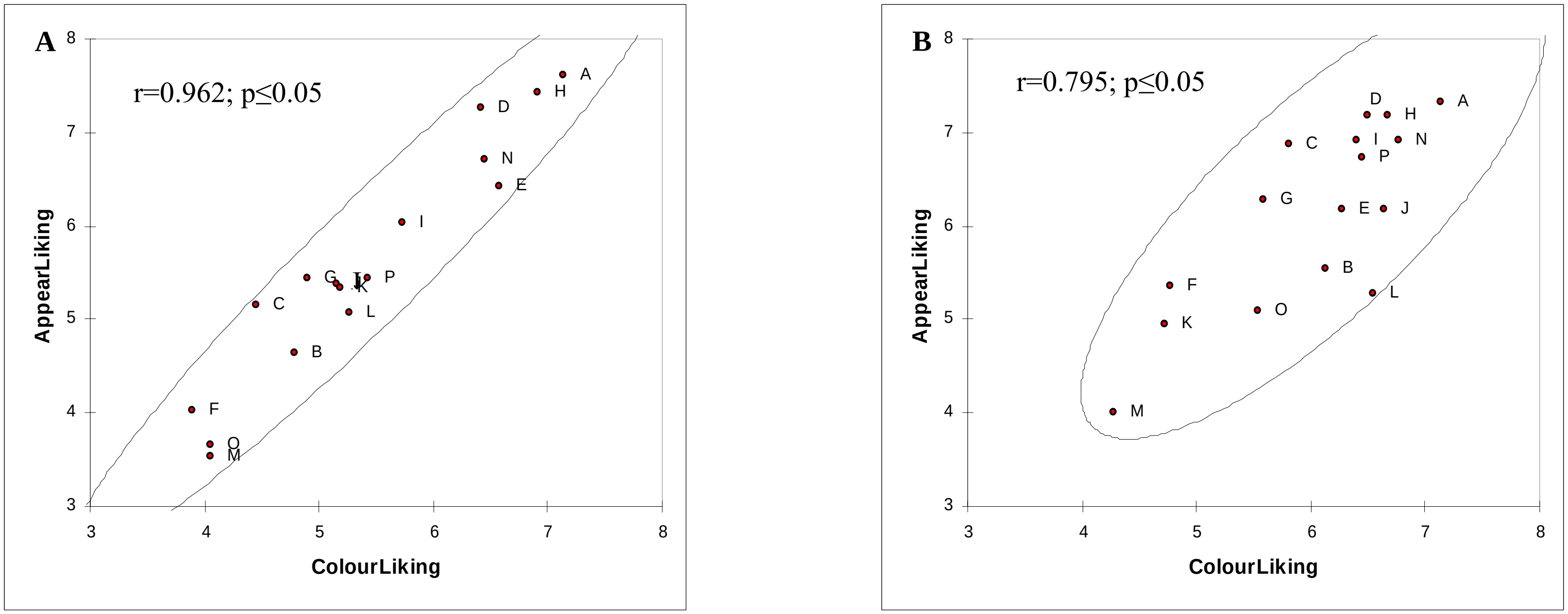

Figure 5.2 Scatter plot of overall means of degree of liking of appearance and colour by the continental European (A) and Great Britain (B) consumer groups. The degree of liking was: dislike extremely (1); dislike very much (2); dislike moderately (3); dislike slightly (4); neither like nor dislike (5); like slightly (6); like moderately (7); like very much (8); like extremely (9). The willingness to pay was: below average (1); average (2); above average (3). The pears were: Concord (A); Simulated Red d'Anjou (B); Bosc (C); Red Rosemarie (D); Abate Fetel (E); Bon Rouge (F); Golden Russet Bosc (G); Bon Chrétien (H); Flamingo (I); Cheeky (J);Conference (K); Forelle (L); Ya (M); pink Rosemarie (N); Red d'Anjou (O); simulated Cheeky (P).

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CHAPTER 6

General discussion and conclusions

The practice of Sensory Science has been proven to be successful in research and development and in the quality assurance in the food and beverage industries (Meilgaard *et al*., 1999). Sensory analysis can also be used to link product development and marketing (Moskowitz, 1994). Consumer preference ratings are of a hedonic nature as they do not give any descriptions, only which product they prefer. Therefore, it is necessary to relate external information about the products to consumer preference ratings, not only to understand the market, but also to generate a successful new product (McEwan *et al*., 1998).

The aim of pear breeding for the Agricultural Research Council (ARC) Infruitec-Nietvoorbij, South Africa, is creating new cultivars with a local as well as export market potential. The new cultivars should have a good adaptation to the local market and environment conditions, which also includes the replacement of existing cultivars. The ARC has two projects on pears, the one project is the breeding of new cultivars and the other is the Phase 2 evaluation of new selections in different regions (Ceres and Elgin, both in Western Cape, South Africa). The research and development committee of the ARC decides on which selections have any future potential. For example, ten years ago the development of the miniature pear cultivar created no interest, but recently a Plant Breeder's Rights (PBR) was applied for, for five new miniature pears, including one blushed variation. Presently the market for fully red pears is almost non existent, but with the right cultivars, this can change (Human, 2007).

New genes are being incorporated through conventional breeding into the development of new cultivars, such as pears with a strong aroma. Asian pears (*P. pyrifolia* Nakai) have also been incorporated in crosses, and fully red, round Asian hybrid selections have already been realized. The characteristics that are concentrated on when for breeding are taste, where high sugar content (sweet taste) with a strong pear flavour is desired, and a long storage potential of at least eight weeks is required. Unique products are the main focus and the supermarkets would like to have a range of new cultivars starting from early to late harvesting time (Human, 2007).

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The first sensory analysis and consumer preference study completed during 2007 was carried out on local, South African, pear consumers. This showed that appearances as well as taste are important factors for pears. Regarding appearance, dark or dull skin colours with a low chroma value were less preferred than brighter colours such as yellow or green ground colours with a light pink or red blush. Pear flavour, juiciness, sweet taste and melt character are the most important flavour or texture attributes for consumers' preference of taste. Sour taste had a negative effect but the TSS/TA ratio proved that a sweet and sour balance is desired. The presence or absence of peel had no effect on the results obtained.

During 2008, a sensory study was executed which was similar to the one performed during 2007, also on local, South African, consumers. The effect of the peel was not measured but an established cultivar, Williams Bon Chrétien, was used as a control in the sensory analysis to help standardise the tasting panel. Again, preference of appearance was greatest for a blushed colour skin, and green and yellow skin colours were also highly preferred. Shape had an influence where typical pear shapes were most preferred. Round shaped genotypes were the least liked, regardless of the skin colour. The sensory attributes, juiciness, pear flavour, sweetness and melt character were statistically concluded to be a driving force for preference of taste. The maturity indicators, hardness, crispness and crunchiness, showed a negative correlation as well as the negative texture characteristic, mealiness, associated with being overripe.

The second study completed during 2008 was focused on the preference for appearance of pears among European consumers. The colour of two of the pears was digitally manipulated and the photographs of these were presented to consumers. Shape did play a role seeing as, when the pear was round, it was marked lower for the degree of liking of the overall appearance than for colour. Overall, green, yellow and light blush colours were preferred and brighter colours were preferred over dull or darker colours. The simulated pear colours were brighter than the original and received higher preference ratings for colour and overall appearance than their original pear cultivar. Cultivars with a dark red blush covering a large portion of the pear with a green or yellow ground colour such as 'Cheeky', 'Flamingo' and 'Forelle' received only a moderate degree of liking for colour whereas 'Forelle' is very popular in Europe and do receive high prices for these pears that are well coloured. The angle at which photographs were taken caused the pears to look like full red pears which may have caused the decrease in preference.

This research was the first attempt at incorporating sensory analysis and consumer preference studies into the process of developing new cultivars in South Africa. As the results

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from both years were consistent, the South African consumer preference for pear appearance and taste is understood. These results were also similar to previous studies performed internationally by other researchers. The pear appearance study performed on European consumers also showed a similar outcome. These European consumers were predominantly older with almost 30% over 60 years of age whereas approximately 90% of the South African consumers used in the previous studies were between 18 and 30. There was a similar preference for colour over the three research chapters and the consumers were from various origins and differed in age and gender. These factors did not seem to play a major role in the outcome of the results and the possibility of using South African consumers when selecting cultivars for the export market exists.

Jaeger *et al*. (2003) found that consumer would normally choose a cultivar that they are familiar with over another that they do not recognise. Red or brown coloured and round shaped pears did not receive high preference among the South African or European consumers and neither in other research conducted internationally (Gamble *et al.*, 2006; Kappel *et al.*, 1995). The New Zealand consumers did, however, have a slight preference for these types of pears (Jaeger *et al*., 2003), but due to the extensive availability of *P. pyrifolia*, these characteristics are what they are familiar with. The breeding of red, round Asian hybrid selections may therefore not be an immediate success with the consumers. In time these types may become popular due to being more widespread and available. Regarding taste, the breeding program is focussed on sweet taste and pear flavour which were attributes that contributed greatly to driving the preference of taste among the South African consumers. Melt character and juiciness were also important to these consumers. These results were consistent with studies performed internationally (Jaeger *et al*., 2003; Kappel *et al*., 1995; Turner *et al*., 2005). Consumer preference of new cultivars can therefore be accurately conducted on local, South African, consumers at a lower cost.

Although the preference among European consumers was for a light blushed pear, the production of these cultivars has been causing problems. The sensitivity to high temperatures causes a decrease in red pigment (Steyn *et al*., 2004). Therefore, unmarketable green pears without pigment have resulted during some seasons. The ARC therefore aims to breed new blushed selections which do not loose colour during high temperatures. Breeding of selections with a deeper pigment (‘Cheeky’) has been done to try to overcome this problem (Human, 2005). The preferences for this colour pear is, however, lower. A possible solution to this could be the production of light blushed pears but in the case of a loss of pigment, the cultivar can still be marketed as a full green or yellow cultivar. Thereby, the producers will

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still receive compensation for their produce if the colour is lost but if not, a higher premium be received.

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