PREFERENCE OF WESTERN CAPE PROVINCE CONSUMERS FOR THE EATING QUALITY AND APPEARANCE OF PEARS

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SUMMARY

Our study aimed to determine the preference of Western Cape consumers for the eating quality and appearance of pears. Identifying the main sensory drivers of liking and consumer groupings with similar preferences may allow the pear industry to target specific markets and increase local consumption, which is stagnating at relatively low levels.

Our first trial included 9 European pear cultivars (*Pyrus communis* L.) and one Asian pear cultivar (*P. pyrifolia* (Burm.) Nak.). These were chosen to represent a wide range of characteristics in order to identify the main sensory drivers of liking and possible consumer groupings. The majority of the 421 consumers, irrespective of gender, ethnicity and age, preferred pears with a distinct pear flavour, a sweet taste, a fair amount of malic acid, soft, juicy flesh with melt character, and a yellow or pale green peel colour with a typical pear shape. Astringency, sourness and grittiness negatively affected consumer preference. None of the pears were mealy and therefore we could not assess this characteristic. Two consumer clusters with similar preferences for eating quality and also for appearance were identified. In terms of eating quality, group 1 (55% of consumers) indicated a liking for a wide range of cultivars with poorly defined likes and dislikes. Group 2 (45% of consumers), in contrast, had a high liking for the eating quality of a small selection of cultivars while disliking the rest. Based on the preferences for appearance, group 1 (61% of consumers) again indicated a liking for a wide range of cultivars. Group 2 (39% of consumers) scored the most familiar cultivars, viz. Bon Chretien and Packham's Triumph, very high and the other cultivars much lower than group 1.

The objective of our second study was to investigate consumer preference for firm, juicy pears compared to soft pears with a melt character and to identify which of 'Forelle', 'Packham's Triumph' and 'Abate Fetel' is best suited to either option. Pears were harvested within the commercial harvest window (H1) (flesh firmness at 6-6.8kg, 6.4-7kg and 6-6.8kg respectively) and again a month later (H2). H1 and H2 pears were ripened at room temperature (20 ºC) for seven or one day, respectively. More consumers (67%) correlated positively with melt character, juiciness, overall pear flavour and sweet taste. These characteristics were the most prominent in H1 'Packham's Triumph' pears while H2 fruit were much firmer, but lower in preferred

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flavour characteristics. There is, however, also a market for crisp and juicy pears as 33% of the consumers showed a preference for these characteristics. 'Forelle' and 'Abate Fetel' could both be suitable for this market. 'Forelle' was preferred firm, probably because H1 soft pears were more astringent and sour as well as less juicy than H2. There was no difference in preference between H1 and H2 in 'Abate Fetel'.

In conclusion, most Western Cape consumers prefer European pears with the characteristic soft, melting texture, but a third of consumers seem to like firm, juicy pears. Hence, there is opportunity to develop a market for tree-ripe and Asian pears, but marketing will be needed to overcome appearance preferences.

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OPSOMMING

Ons studie was daarop gemik om die voorkeur van Wes-Kaap verbruikers vir die eetkwaliteit en voorkoms van pere te bepaal. Die identifisering van die belangrikste sensoriese drywers van smaakvoorkeure en verbruikersgroepe met soortgelyke voorkeure kan die peerbedryf toelaat om spesifieke markte te teiken en plaaslike verbruik te verhoog, wat tans op relatief lae vlakke stagneer.

Ons eerste proef het 9 Europese peer kultivars *(Pyrus communis* L.) en een Asiatiese peer kultivar *(P. pyrifolia* (Burm.) Nak.) ingesluit. Die kultivars is gekies om 'n wye verskeidenheid eienskappe te verteenwoordig sodat die belangrikste drywers van sensoriese smaakvoorkeure en moontlike verbruikersgroeperings geïdentifiseer kon word. Die meerderheid van die 421 verbruikers, ongeag geslag, etnisiteit en ouderdom, het pere met 'n duidelike peer geur, 'n soet smaak, 'n redelike hoeveelheid appelsuur, sagte en sappige tekstuur met n smeltkarakter, en 'n geel of liggroen skilkleur met 'n tipiese peer vorm verkies. Frankheid, hoë suurvlakke en grinterigheid het verbruikers voorkeur negatief beinvloed. Geen pere in ons studie was melerig nie en daarom kon ons nie hierdie eienskap evalueer nie. Twee verbruikersgroepe met soortgelyke voorkeure vir eetkwaliteit en peervoorkoms is geïdentifiseer. In terme van eetkwaliteit het groep 1 (55% van die verbruikers) 'n voorkeur vir 'n wye verskeidenheid van kultivars aangedui. Groep 2 (45% van die verbruikers) daarteenoor het die eetkwaliteit van net 'n klein seleksie van kultivars verkies, terwyl hul ‘n afkeur getoon het vir die res. In terme van voorkoms, het groep 1 (61% van die verbruikers) weereens van 'n wye verskeidenheid kultivars gehou terwyl groep 2 (39% van die verbruikers) baie hoë punte aan die bekende Bon Chretien en Packham's Triumph kultivars toegeken het, maar die ander kultivars baie laer as groep 1 bepunt het.

Die doel van ons tweede proef was om verbruikersvoorkeur vir ferm, sappige pere teenoor sagte pere met 'n smelt tekstuur te bepaal en tot watter mate 'Forelle', 'Packham's Triumph' en ‘Abate Fetel' geskik is vir iedere opsie. Pere is tydens die kommersiële oesvenster (H1) (fermheid 6-6.8kg, 6.4-7kg en 6-6.8kg onderskeidelik) en weer 'n maand later (H2) geoes. H1 en H2 pere is teen kamertemperatuur (20 ºC) onderskeidelik vir sewe of een dag rypgemaak. Die meeste verbruikers (67%) se voorkeur korreleer positief met 'n smeltende tekstuur, sappigheid, peer geur en soet

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smaak. Hierdie eienskappe was die prominentste in H1 'Packham's Triumph' pere terwyl H2 vrugte baie fermer, maar laer in voorkeur geureienskappe was. Daar is egter wel 'n mark vir ferm, sappige pere aangesien 33% van die verbruikers 'n voorkeur toon vir hierdie eienskappe. 'Forelle' en 'Abate Fetel' sou beide geskik kon wees vir hierdie mark. 'Forelle' is verkies as 'n fermer peer, waarskynlik omdat H1 sagte pere meer frank, suurder sowel as minder sappig was. Daar was geen verskil in verbruikersvoorkeur tussen 'Abate Fetel' se H1 en H2 pere nie.

Ten slotte, die meeste verbruikers van die Wes-Kaap verkies die smaak van ryp Europese pere met hul karakteristieke sagte, smeltende tekstuur, maar 'n derde van die verbruikers hou wel van ferm, sappige pere. Daar is dus 'n geleentheid om die mark vir boomryp en Asiatiese pere te ontwikkel, maar bemarking sal nodig wees om die verbruikersvoorkeure vir voorkoms te oorkom.

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DEDICATION

To my parents Antoinette and Callie Theron and to Bill Hulme for all the myriad of ways they have encouraged and supported me.

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GENERAL INTRODUCTION

South Africa produces 3% of the global pear output and pears account for 16% of the local deciduous fruit industry (HORTGRO, 2015). In South Africa, only European pears (*Pyrus communis* L.) are produced and the major cultivars grown are green Packham's Triumph (33%), red-blushed Forelle (26%), yellow Bon Chretien (22%) and yellow-brown Abate Fétel (6%) (HORTGRO, 2015). These are old cultivars with Packham's Triumph originating from Australia ca 1897, the youngest and Forelle originating in Germany ca 1864 the oldest (Agricultural Research Service, 2009). Locally bred, new cultivars like Cheeky and Rosemarie contribute only 7% to total plantings (HORTGRO, 2015).

South Africa is rated as the seventh largest exporter of pears in the world (Belrose Inc., 2015). Currently, only 15% of total production of ca 414,000 tons is absorbed by the fresh local market (HORTGRO, 2015) while 48% is exported, mainly to the European Union and The United Kingdom (HORTGRO, 2015). Local consumption of pears compares poorly to consumption of apples, which amounts to 29% of the total production of 793,000 tons. In order for South Africa to stay competitive on the overseas markets and grow the local market as well, it is important to produce top quality fruit that appeal to consumers.

The concept of quality of a pear at harvest, and during or after storage is different from that of fruit at the time of consumption (Predieri *et al.,* 2005). Since consumption is the end point of the product, it has therefore been suggested that fruit quality should be defined from the consumer's perspective as the final user of the product (Predieri *et al.,* 2005). Fruit quality is of paramount importance as it forms the basis of consumer satisfaction in fresh produce (Jaeger *et al.,* 2002). Knowledge of consumer expectations on food quality should underpin successful food production and marketing (Peneau *et al.,* 2006).

Eating quality of fruit, however, is difficult to measure objectively. Sensory analysis is therefore a vital tool in characterisation of different cultivars and defining sensory attributes relating to consumer preference, such as texture (soft or hard), juiciness, sweetness and pear flavour, all of which are important determinants of eating quality in pears (Eccher Zerbini, 2002; Vaysse *et al*., 2005). In general, European pears with a good eating quality have a juicy, buttery and melting texture with a strong pear flavour, although there are consumers that prefer pears with a crispy and juicy texture (Hoehn *et al.,* 1996). Asian pears (predominantly *P. pyrifolia* ((Burm. f.) Nakai)) are typically crispy and juicy, while European pears can also be marketed as such after treatment with the ripening inhibitor 1-methylcyclopropene (Smartfresh^{TM}, AgroFresh Inc., Philadelphia, PA, USA) (Crouch and Bergman, 2013). The preference of South African consumers for the eating quality and appearance of such pears is uncertain.

Our study was undertaken as collaboration between the Departments of Horticultural Science and Food Science at the Stellenbosch University, South Africa and consisted of two separate research projects. The first investigation was undertaken during 2012 to identify the preference of Western Cape Province consumers of different ethnicities, age groups and genders for eating quality and appearance of 10 pear cultivars, including one Asian cultivar. Cultivars were selected in such a way that a wide range of pear characteristics were offered so that the main sensory drivers of liking and possible consumer groupings could be identified. The second study was carried out during 2013 and was similar to the first experiment but with the emphasis on the effect of harvest time and ripeness on consumer preference of 'Forelle', 'Packham's Triumph' and 'Abate Fetel' pear eating quality and appearance. The objective of this study was to investigate consumer preference for the sensory attributes of pears that can be used to identify pear cultivars and harvest/post-harvest treatments that will satisfy consumer preferences. The two research chapters are preceded by a literature study focusing on world pear production, research conducted on preference for pear appearance and eating quality, and the correlation between the physicochemical and sensory attributes and assessments used to describe pear quality.

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Literature review: The pear industry, fruit quality and consumer preference

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Chapter 1

Literature review

The pear industry, fruit quality and consumer preference

1. Introduction

Due to growing competitiveness in the marketplace, the fruit industry has started to focus more on the needs and desires of consumers. This is similar to the process previously experienced in the manufactured food sector (Jaeger *et al.*, 2003). The quality of fruit is a keystone in building consumer satisfaction and Jaeger and MacFie (2001) define quality as all those characteristics that lead to a consumer being satisfied with the product.

Greater pressure is placed on breeders and growers to keep developing new cultivars that satisfy the changing needs of the marketplace (McKenna *et al.*, 1998). In order to accomplish this, the fruit industry is now using tools that research, development and marketing personnel in the manufactured foods sector have used so successfully. The most important of these techniques is preference mapping (Jaeger *et al.*, 2003).

Preference mapping is described as a group of multivariate statistical techniques intended to develop a deeper comprehension of consumer acceptance of goods (Society for sensory professionals, 2015). The main benefit of preference mapping is the ability to discover the sensory attributes driving preference. Sensory profiles usually include internal attributes like texture, flavour and aroma, as well as external appearance, as a consumer is likely to use the latter as the basis for choice of purchase, unless they are already acquainted with the product (Jaeger *et al.*, 2003). The lengths that the fruit industries go to for achieving standardised appearance of produce in supermarkets is an indication of the importance of appearance (Jaeger *et al.*, 2003).

While numerous studies have been done on consumer preference of apples, little research has been done on consumer preference of pears, especially in South

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Africa. There are now over 5,000 varieties of pears cultivated in temperate climates worldwide (Herbst, 2001). Sensory analysis can provide pear breeders and the pear industry with a better understanding of consumer preferences regarding pear eating quality and appearance. This can allow them to breed more desirable pears and also to focus marketing of pears with specific attributes to the appropriate consumer groups (Hampson *et al*., 2000).

In an ethnically diverse country like South Africa, there may be a number of different market segments with different needs and preferences. This chapter provides an overview of the pear industry in the world and South Africa in particular, followed by aspects that influence consumer acceptance of pears and how consumer preference can be measured.

2. The pear industry: an overview

World pear production increased by almost 50% between 1997-99 to 2008-10 (Belrose Inc., 2015). Almost all of the growth we have seen in the pear industry over the last decade is due to China doubling production of *P. pyriofolia* and other Asian pear species, currently accounting for almost 72% of world pear production (Belrose Inc., 2015).

World pear production is forecast to increase by 4% to 24.2 million tons due to increased production in China (USDA, 2015). Isolated gains in pear production were seen in Africa and Russia, with small increases in Asia outside of China and the EU.

There have, however, been declines in the major production areas of North and South America, Oceania and Europe. From 1997 – 2010, production of European pears has shown only modest growth, yet production of Asian pears have increased every year (Belrose Inc., 2015). Global trade is projected to decrease by 6%, driven by lower shipments from Argentina, the EU, and the United States (USDA, 2015).

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Table 1: Global pear production in 2013 (tons) and the area (ha) harvested in the ten most productive countries. Adapted from FAO (2015).

Rank	Country	Production (tons)	Area harvested (ha)
1	China	16,723,000	1,136,700
2	USA	815,000	22,015
3	Argentina	787,000	26,500
4	Italy	772,000	35,195
5	Spain	425,000	34,067
6	Turkey	461,000	25,000
7	South Africa	343,000	14,353
8	India	340,000	38,500
9	Japan	302,000	13,000
10	Netherlands	289,000	14,900

2.1 Northern Hemisphere

China

The world leader in pear production is undoubtedly China with an annual output of more than 16 million tons accounting for 65.7% of world production and 72.3% or 1.14 million hectares of world growing area in 2012. The pear industry is also the third largest fruit industry in China after oranges and apples. Chinese pear production consists mainly of *P. pyrifolia* and *P. ussuriensis* according to Segrè (2002) while Teng (2011) also includes the Xinjiang pear (*P. × sinkiangensis*) as one of the main groups of commercial pears grown in China.

Most pears are consumed fresh in China with only about 8% being processed (Teng, 2011), compared to Europe where 20% of total pear production is processed (Deckers and Schoofs, 2008). In China, 96.7% of pears grown are consumed by the domestic market with only 3.3% exported mainly to Vietnam, Thailand and Indonesia. China has surpassed Argentina and is currently the largest pear exporter (Teng, 2011). China's production is predicted to continue expanding by 7% to a

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record 18.5 million tons on increased plantings. Exports are expected to rise with 9% to 325,000 tons driven largely by shipments to Russia (USDA, 2015).

Europe

In Northern Europe, pears (mainly the European pear *P. communis* L.) contribute 5 – 15% to pome fruit production (Bünemann, 2002) and countries in the European Union supply a mere 25% of Northern Europe's requirements (Mazzotti *et al*., 2002). Total pear production in Europe fluctuates between 2 and 2.5 million tons and has remained relatively stable during the last few years with Italy and Spain being the most important countries accounting for more than 65% of total production. They are followed by The Netherlands, Belgium, Portugal, and France (Belrose Inc., 2015).

The extension of the European Union from 15 to 25 member state countries has had a limited influence on pear production as only Poland and Hungary have significant pear growing areas of 13,000 ha and 3,200 ha respectively (Belrose Inc., 2015).

The EU's production is forecast to remain flat at 2.4 million tons (USDA, 2015). Russia and specifically Moscow and St. Petersburg were emerging as fast growing markets for European grown pear fruit (Deckers and Schoofs, 2008) until 6 August 2014 when Moscow announced an embargo on imports of agricultural products from the EU.

One year on, the EU agri-food sector has been remarkably resilient. Alternative markets have been found, either within the EU or beyond, for example, the opening of the Canadian market for pears from Belgium (European Commission, 2015). Exports are forecast to decrease by 10% to 425,000 tons as continued effects of Russia's ban are partially offset by gains in Eastern Europe and North Africa. Imports are expected to decrease by 10% to 230,000 tons due to lower demand (USDA, 2015).

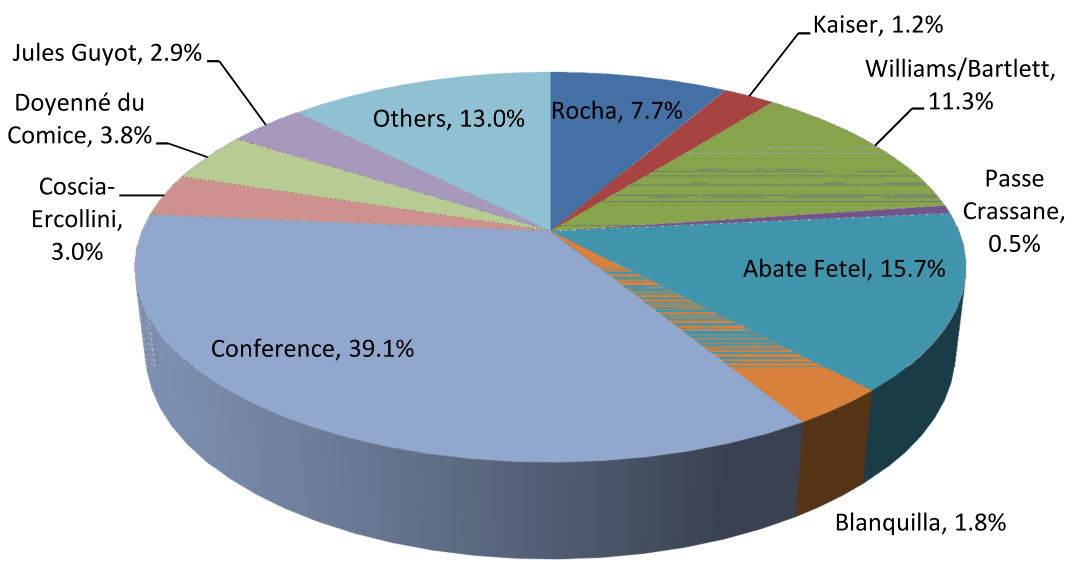

Figure 1. Distribution of the pear production in Europe by cultivar in 2014. Source: Belrose Inc. (2015).

North America

In North America, 98% of pear production is concentrated in Washington, California, and Oregon on the West Coast and represents 42%, 32% and 23%, respectively (Mielke, 2008). They rely mostly on three cultivars, viz. Bartlett (William's Bon Crétien) 47%, Beurré d'Anjou 39% and Beurré Bosc 11% for commercial sales (Belrose Inc., 2015). The U.S pear industry is under pressure as many producers have expanded into apples, grapes or sweet cherries over the last decade causing a slow attrition of the pear sector.

Production is forecast to decrease by 8% to 732,000 tons on lower yields in major producing states (USDA, 2015). From 1997 – 2007 there was a 22% decrease in pear consumption in the U.S. and that trend has continued, with below-average production and higher prices reducing demand for U.S. fresh pears in 2014, domestic per capita use dropped to 1.17 kg, the lowest level in over two decades (USDA, 2014).

The processed market has contracted by 30% over the last ten years and the industry is more dependent on that segment than most countries (Belrose Inc., 2015). As a net exporter of pears, the United States mainly supplies Mexico and

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Canada (Geisler, 2012) and depend heavily on the duty-free access of these neighbouring markets under the North American Free Trade Agreement (Belrose Inc., 2015).

2.2 Southern Hemisphere

The five major producing countries in the Southern Hemisphere, viz. Argentina, Australia, Chile, New Zealand and South Africa, supply 75% of Northern Europe's pears. Collectively they have a major influence on off-season markets in the Northern Hemisphere (Belrose Inc., 2015).

Argentina

Argentina is the largest pear producer in the Southern Hemisphere, harvesting about 700 000 tons annually (FAO, 2015). Due to the outstanding ecological conditions for growing pears, the area of pears planted has been increasing, by over 20% in the last decade (Belrose Inc., 2015). The main cultivars grown are Williams' Bon Crétien making up around 50% of the total plantings, followed by Packham's Triumph and Beurre d'Anjou. The domestic market consumes 15% and the rest are exported mainly to Brazil, USA, Italy and Russia (Sanchez, 2008). This year, however, Argentina's production is forecast to decline by 12% due to hail damage as well as large volumes of unharvested fruit as a result of labour issues and rising input costs (USDA, 2015).

Chile

Ranked 14th on the list of top pear producing countries (Belrose Inc., 2015), Chile harvesting about 202 000 tons annually, together with Argentina, account for 90% of South American pear production. The planted area has decreased in recent years to about 11125 ha of European pears. Despite the reduced area, production stayed relatively stable due to yield increases. The main cultivar is Packham's Triumph followed by Beurré Bosc and Forelle (Belrose Inc., 2015). It is a net exporting country with half of pear exports going to Europe and the rest to Latin America, USA and the Middle and Far East (USDA, 2015). Chile's pear production is forecast to rebound by 9% due to favourable growing conditions (USDA, 2015).

Australia

Australia accounts for 0.7% of world pear production (Belrose Inc., 2015). Production of *P. communis* L. (European pear) has remained relatively stable since 2001 with an average of 146000 tons, while *P. pyrifolia* (Asian pear) production averages at around 3500 tons. The major European pear cultivars produced are William's Bon Crétien 48%, Packham's Triumph 40% followed by Beurré Bosc 7%. *P. pyrifolia* has also been produced since the 1980s with Nijisseiki being the main cultivar of choice. *P. pyrifolia* is used fresh with about 35-40% of the European cultivars sent for processing and 5-10% exported (Palmer and Grills, 2008). Once one of the leading suppliers of fresh pears to the Northern Hemisphere markets, Australian exports have declined due to a series of natural disasters and the strength of the Australian dollar (Belrose Inc., 2015).

New Zealand

Pears represent only 3.5% of fruit production in New Zealand (White and Brewer, 2002). The 28 420 tons harvested annually mainly serves the small domestic market (Belrose Inc., 2015). The European pear production is dominated by Doyenné du Comice and its fully russetted mutation Taylor's Gold followed by the cultivar William's Bon Crétien that is used mostly for processing, as well as Beurré Bosc. These cultivars have mostly replaced the previous cultivars such as Packham's Triumph, Winter Nelis and Winter Cole (Palmer and Grills, 2008). The major export markets are Europe and USA, however, only 12% of the total production is exported (White and Brewer, 2002). Prevar™ is an incorporated New Zealand-registered joint venture company established to globally commercialise the new apple and pear cultivars bred in New Zealand by crown research organisation Plant and Food Research (PFR). Their objective is to assist Australian and New Zealand growers in such a manner that will achieve sustainable profits from the new cultivars. One of their projects is the breeding of interspecific pears under the Piqa® brand (Prevar, 2014). These pears are conventional hybrids of European and Asian pears and are

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bred to have interesting and unusual flavours, some of which have not been found in pears before such as tropical fruit, tropical pear, melon, coconut and plum as well as familiar European pear flavours. Piqa® brand fruits are 'ready to eat' at harvest (Prevar, 2014).

South Africa

The pear industry in South Africa, with its well balanced mix of production and markets, continues to expand slowly with total production rising by about 2 percent per year (Belrose Inc., 2015). South Africa produces 3% of the global pear output and pears make up 16% of the local deciduous fruit industry (HORTGRO, 2015). The main production areas are Ceres, where 38% is cultivated, followed by the Langkloof 14% and Wolseley/Tulbagh 12% (HORTGRO, 2015). The total area planted to pears is 12 211 ha (HORTGRO, 2015).

The major cultivars grown (Figure 2) are Packham's Triumph (33%), Forelle (26%) and Bon Chrétien (22%) with other important cultivars Abate Fétel (6%), Rosemarie (4%), Beurré Bosc (2%), Cheeky (2%), Doyenné du Comice (1%), Flamingo (1%) and Golden Russet Bosc (1%) (HORTGRO, 2015). In order to keep the South African pear culture competitive it is necessary to develop unique, acclimatised and profitable varieties. There has been a shift in production towards blushed or bi-coloured cultivars with Forelle being the most important of these (Theron *et al*., 2008).

As blushed pears obtain good prices on European markets, it is of importance to South Africa, one of the few countries producing these pears, to maintain and further develop this market segment (Von Mollendorf, 2008). The newest blushed cultivar developed in South Africa by the pear breeding team of the Agricultural Research Council (ARC) is Cheeky, released to growers in May 2009 (Von Mollendorf, 2008). 'Cheeky' is currently being grown on 350 hectares in the Western Cape, with around 100 ha are already in commercial production (Watson, 2014).

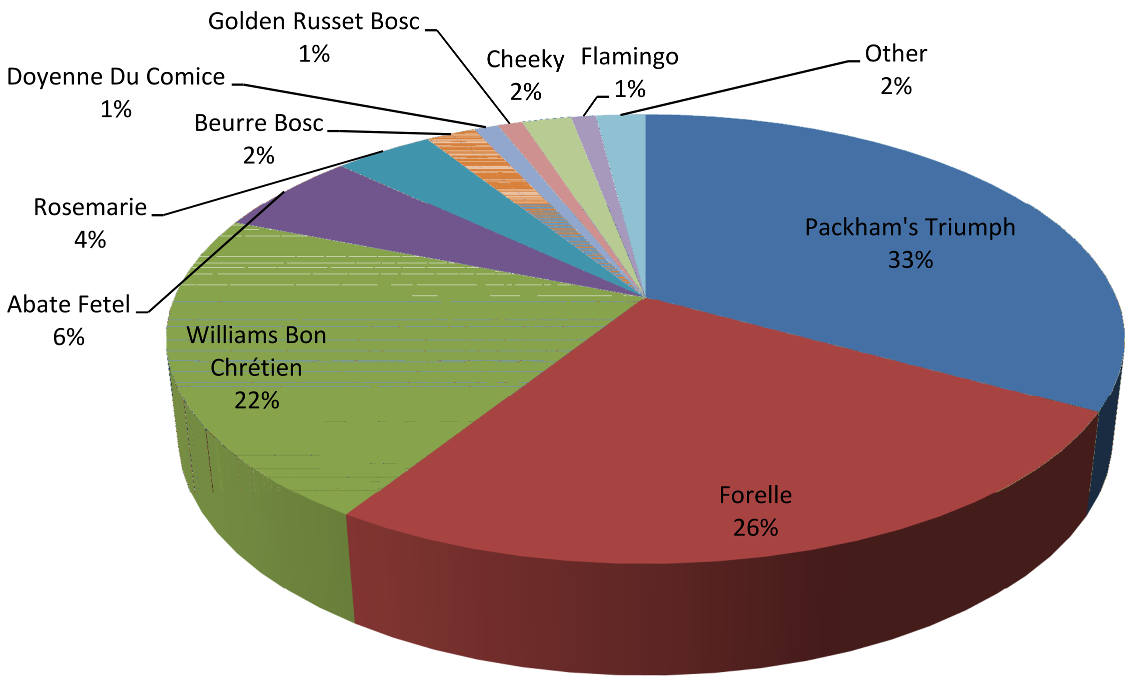

Figure 2. Distribution of the pear production in South Africa by cultivar. Source: HORTGRO (2015).

Of the 413614 tons total production in 2013/14, 35% was processed with a small amount, 2%, being dried and 48% exported, mainly to the European Union and The United Kingdom, with smaller volumes going to the Far East, Middle East, North America and the rest of Africa (HORTGRO, 2015; PPECB, 2014).

South Africa is rated as the seventh largest exporter of pears in the world (Belrose Inc., 2015). Currently only 15% of total production is absorbed by the fresh local market (HORTGRO, 2014). Per capita consumption of pears is very low in South Africa at 0.96 kg in 2014, while other countries consume much more, e.g. Italy, have a per capita consumption of 9.27 kg (Belrose Inc., 2015). This illustrates how much potential room for growth there is in the local market.

3. Aspects of consumer preference

Marketing can be described as those activities in an economy that direct the flow of products and services from the producers to the consumers in such a way that it leads to the largest possible needs-satisfaction of the community as a whole (Lucas *et al.*, 1979). For decades farmers have grown pears and then relied on marketing agents to find countries, retailers and customers that desire their product enough to pay a price that will not only cover expenses, but ensure a decent profit for everyone in the value chain. Cultivars have been selected based on orchard-oriented criteria such as disease resistance, high yields and shelf-life. These are important criteria, but of even greater importance are those product attributes that will entice consumers to buy the fruit and become regular consumers of pears (Belrose Inc., 2015).

The individual consumer has a set of preferences that are inter alia dependent upon culture, education and individual taste. They make decisions by allocating their income across all possible goods in a way that gives them the greatest satisfaction.

It has therefore been suggested that fruit quality should be defined from the consumer's perspective as the final user of the product (Predieri *et al.*, 2005). Defining what exactly quality is, remains a dilemma. It is a subjective attribute and means different things to different people. For the producer, size, freedom from defects and packout percentage are important and to the wholesaler the durability or keeping quality is important, but from the final buyer, the consumer's perspective, appearance is the first factor that influences purchase decision, followed by perceived value for money and fruit eating quality (Eccher Zerbini, 2002). It is this last factor, eating quality, which is the most troublesome issue for everyone (Kanlayanarat and McGlasson, 2003). It is difficult to measure eating quality objectively and standard analytical measurements have shown poor correlation with sensory perception (Predieri *et al.*, 2005).

Fruit eating quality has been defined as all those characteristics of a fruit that lead a consumer to be satisfied with the product (Jaeger *et al.*, 2003). This includes many attributes such as appearance, texture and flavour, defects and nutritional value (Abbott, 1999). To the consumer, fruit quality is based on several elements, many of which cannot be evaluated before purchase.

External factors of the appearance of fruit, such as colour and shape, can therefore have a large influence on the consumer's first impression and projection of what the fruit may taste like (Jaeger and MacFie, 2001). Food choice and consumer preference studies are complex because besides the main aspects being investigated (e.g. fruit quality or sensory appeal), other factors such as familiarity, habit, social interactions, media, advertising, cost, availability, time constraints and personal ideology also play a role (Pollard *et al.*, 2002). Fruit quality should therefore be considered as a non-absolute variable subject to change (Hamadziripi, 2012).

3.1 Fruit quality.

The word "quality" denotes the level of excellence of a product or its suitability for a particular use; it is a human concept encompassing many characteristics. When referring to fresh produce it refers to sensory characteristics such as appearance, texture, taste and aroma as well as nutritive values and chemical constituents (Abbott, 1999). Fruit eating quality is difficult to measure objectively (Hampson *et al.*, 2000). Factors relating to fruit quality will influence consumers' initial purchase decisions (Corrigan *et al.*, 1997), but if consumers are not satisfied with the eating quality of the product, return sales will be damaged (Harker *et al.*, 2008).

3.1.1 Appearance.

Every product reflects light that carries information used by humans to evaluate it. The initial judgement of a fruit's quality is therefore made on appearance (Jaeger *et al*. 2003). There is a need to guide horticultural product development not only by taste preferences, but also by appearance preferences as consumers are forced to make decisions based on the way a product looks (Gamble *et al*., 2006). Colour is used as the basis for sorting fruit into commercial grades and relates directly to consumer perception of appearance (Abbott, 1999). As some aspects of quality, for example ripening of fruit or the changes associated with senescence, are directly related to colour, it can therefore be viewed as the most important appearance characteristic of foods (Lawless and Heymann, 2010).

Pears are available in a variety of different colours. Kappel *et al.* (1995) found that yellow appears to be the most sought after colour by consumers in Canada, while a slight red blush may be acceptable. Trials done in South Africa, however, concluded that yellow, green and lightly coloured blush pears were preferred (Steyn *et al.*, 2011).

Different shaped pears are available such as pyriform, elongate-concave, intermediate straight and round. Gamble *et al.*, (2006) in a study on Australian and New Zealand consumer preference for appearance in pears found that preference was greatest for green and yellow colours with intermediate-straight or elongate-concave shapes, while, round and red pears were unlikely to be chosen as preferred fruit. In South Africa, Steyn *et al.* (2011) found that the typical pear shape was preferred by consumers and the elongated shape of Abate Fetel and round pears like the Asian cultivars were generally disliked. Preference for shape is based on familiarity and could be culturally linked (Gamble *et al.*, 2006). Research done by Jaeger *et al.* (2003) on New Zealand consumers' preference of pears, revealed a complex segmentation pattern. While some consumers preferred big and elongated/ pyriform shape pears, others rejected brown and dark green colours while still others preferred a round shape and warm golden colours. It is clear that appearance is a critical aspect of acceptance and greater focus on appearance is suggested as one path for further investigation in the search for the 'ideal' pear (Jaeger *et al.*, 2003).

3.1.2 Eating quality

The texture of a product tends to be overshadowed by its flavour (Nicolai *et al.*, 2003). There is, however, a strong interaction between these two attributes, the blander the flavour, the greater the awareness of texture becomes (Szczesniak and Kahn, 2007). In fruit, texture relates to the changes in the cell wall components during ripening (Crouch, 2011; Muziri et al., 2015). It influences the possibility of compounds contained in the cell, like sugars, acids and volatile substances, being released by mastication so it can be perceived by the consumer (Echer Zerbini, 2002). Texture is dependent on many factors like time of harvesting, storage time and conditions, as well as post storage ripening conditions (Carmichael 2011; Crouch 2011; Martin, 2002). If storage time is not ideal, pears may soften with a dry and coarse texture (Crouch, 2011; Echer Zerbini, 2002).

The peel of the fruit represents another aspect of texture and can influence the sensory properties with regard to effort needed to bite into the flesh as well as contributing to the flavour, as it may impart some bitterness or astringency (Amos, 2007). Van der Merwe (2013) in a study on preference for eating quality of apples found that texture was a key driver of liking among South African consumers. Echer Zerbini (2002) found that Italian consumers prefer pears with a juicy, buttery and melting texture while Hoehn *et al.* (1996) reports that there are consumers that prefer pears with a crispy and juicy texture.

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Jaeger *et al*. (2003) found strong negative correlations between crispness, crunchiness and hardness and the degree of liking for taste, confirming a preference for a softer pear. Grittiness and mealiness were also thought to be negative characteristics.

Mealiness is an umbrella term for fruit flesh developing a textural disorder characterised by coarse, floury, soft and dry texture (Andani *et al*., 2001; Barreiro *et al*., 1998; Harker and Hallet, 1992). Mealiness is the key internal quality disorder associated with the sensory quality of 'Forelle' pears in South Africa (Carmichael, 2011; Crouch, 2011; Martin, 2002). Steyn *et al*. (2011) investigated the preferences of South African consumers and found them to favour a soft pear with a melting, juicy, but not a mealy texture.

Pear texture of melt ability is an important driver of consumer preference in South Africa (Cronje, 2014). In consumer tests done in the UK and Germany by Crouch and Bergman (2013), it was found that there is a market segment that prefers firmer pears although almost twice as many respondents indicated that they preferred a softer pear to that of a firmer pear. The majority of German respondents, however, indicated that they preferred a firmer to a softer pear (Crouch and Bergman, 2013).

Flavour is comprised of olfactory sensations caused by volatile substances released from the product in the mouth (aroma), gustatory sensations (taste), as well as other chemical sensation factors such as astringency (Meilgaard *et al*., 1987). In research on apples, Van der Merwe (2013) found that sour taste and sweet taste were important drivers of consumer preference in South Africa, while apple flavour had less of an influence.

Cronje (2014), however, found in a study on South African consumer preference of pears that although sweet taste is significant, furthermore for pears, overall pear flavour is a significant driver of consumer preference. Pear taste and flavour is dependent on sugars, acids and volatile substances (Echer Zerbini, 2002). Perceived sweetness and sourness are caused by the composition of soluble sugars, fructose (54-63%), sorbitol (22-31%), glucose (11-15%) and sucrose (4-5%) and organic acids primarily malic acid in pear fruit (Paillard, 1990).

As pears ripen, the percentage sucrose increases while the percentage sorbitol decreases, without changing the Brix value (Drake and Eisele, 1999). Esters of

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decadienoic acid and low boiling point volatiles have been identified as main impact compounds important to imparting pear flavour (Echer Zerbini, 2002). The use of the dynamic headspace sampling system have confirmed a genotype-dependent volatile emission pattern of pear fruit and can be used to identify handling practices to enhance pear volatile emission to optimise eating quality (Rapparini and Predieri, 2002).

4. Physical, chemical and sensory attribute analysis

In a highly competitive environment, like the fruit industry, customer contentment is a key point in determining overall product quality and market value and should be thoroughly analysed when planning production and marketing strategies (Gatti *et al.*, 2011). The physical and sensory properties of a food are the most important factors influencing consumption. It is therefore very important that accurate and unbiased methods be used to measure these properties and to be aware of the special requirements necessary when humans are employed as scientific measuring instruments.

4.1 Physical analysis

Using instruments to measure the physical and chemical properties of a product does not mimic the eating process and therefore the data do not necessarily relate to the eating quality (MacFie, 1990). For quality assessment of fresh fruits and vegetables, instrumental methods are still preferred to sensory analysis, which is preferred over consumer testing, regardless of the fact that the different approaches are in opposite order in terms of extrapolation of results to the real world (Shewfelt, 1999). Objective measurements of sensory characteristics are important for breeding purposes (King *et al.*, 2000). The fruit industry also has legal standards for edible quality that are based on numerical ranges that are obtained by instrumental measurements (Harker *et al.*, 2008). Instrumental measurements that can reliably predict sensory data would therefore greatly benefit industry (Harker *et al.*, 2002).

Typically, the physical measurements of mass, length, colour, dry mass concentration (DMC) and firmness are taken along with the chemical measurements of total soluble solids (TSS) and titratable acidity (TA). DMC has increasingly been a research focus as it relates to maturity e.g. avocado (Gamble *et al.*, 2010) or to consumer preference in itself. Palmer *et al.* (2010) provides evidence of a good correlation between consumer preference and DMC for 'Royal Gala' apples. The biological processes responsible for setting up the textural characteristics, carbohydrate status and flavour potential of the fruit are specifically represented by DMC and it has been proposed that fruit DMC be used as a new quality metric for apples (Palmer *et al.*, 2010). Cronje (2014), however, found DMC to be a negative driver of liking for eating quality of 'Forelle' pears since outer canopy pears, which tended to have higher DMC, were also more prone to mealiness.

Flesh firmness is measured on opposite sides of each fruit using a penetrometer with a plunger tip and expressed in N, the size of the plunger tip selected depends on the fruit being measured; 11 mm for apples and 7.9 mm for pears are standard (Wills *et al.*, 2007; Van der Merwe 2013; Cronje, 2014). Salvador *et al.* (2007), evaluating consumer acceptability and shelf-life of pears, used a TA-XTplus Texture Analyser (Stable Micro Systems, Godalming, U.K.) to evaluate the texture of the pear samples. A compression test was performed with a 75-mm aluminium compression platen (P/75) to an 80% strain, with a test speed of 1 mm/s, a trigger force of 5 g and force in compression mode (Salvador *et al.*, 2007).

The difference between the penetrometer and the texture analyser are the number of texture properties the two methods reveal. The texture analyser is able to distinguish the properties of hardness, firmness, tenderness, springiness, adhesiveness and chewiness while the penetrometer is used to assess firmness and hardness only (Chen and Opara, 2013). Non-destructive techniques like visible near infra-red spectroscopy (VNIR) have also been used for measuring fruit texture (Mehinagic *et al.,* 2004). VNIR spectra (light wavelength ranging from 400 to 2500 nm) were taken on two opposite faces of intact apples using a Visible-NIR spectrometer (NIR Systems 6500, Perstorp Analytical, Nanterre, France). It was concluded that there is actually a statistically significant relationship between different Visible-NIR wavelengths and some sensory attributes for apple. However, this relationship is not currently sufficient to allow the prediction of sensory attributes from VNIR data (Mehinagic *et al., 2004*).

During the chemical analysis, TSS are determined with a hand refractometer using juice pressed from the whole fruit expressed in ºBrix, while TA, is determined by titrating 10 g of juice from each fruit sample with 0.1 N NaOH to pH 8.2 and is expressed as percentage malic acid (Cronje, 2014). Kappel (1995) concluded that the TSS:TA ratio could be a useful indicator of quality in pears.

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Several researchers (King *et al*., 2000; Harker *et al*., 2002; Mehinagic *et al.,* 2004*;* Mann *et al*., 2005), have studied the relationship between instrumental measurements of texture and sensory descriptors. Watada *et al*. (1984) found that standard measurements (TSS, TA) have a poor correlation with sensory perception in apples and the same is true for pears (Predieri *et al*., 2005). Harker *et al.* (2002) found that puncture tests consistently provided a good prediction of firmness, crispness and crunchiness, while Mehinagic *et al.* (2004) found that compression data were a better indicator of juiciness and mealiness than penetrometer measurements. There has been no definite conclusion, however, as to which method or combination of methods can best predict texture. Sensory analysis is becoming a more prevalent method for evaluating fruit eating quality (Predieri *et al*., 2005).

Fruit colour, which plays an important role in consumer acceptability from a quality, maturity signalling and aesthetic perspective, is regulated by pigment composition (Steyn, 2012). To measure pear colour, Kappel *et al.* (1995) identified the ground colour and blush or red pigmentation (Minolta CR-200 chromameter; Minolta, Ramsey, N.J.) as well as the percentage of fruit surface covered by a red blush. Echeverria *et al*. (2004) recorded the hue angle at the reddest i.e. the side that was exposed to sunlight and least red (or greenest) position on each fruit. Cronje (2014) determined the external colour of pears with a chromameter (Model CR-400; Minolta Co., Ltd., Tokyo, Japan), where lightness (L), chroma (C) and hue angle (H) was recorded. The chromameter measurements were taken on the reddest position of each fruit. The lightness coefficient (L*) ranges from black=0 to white=100 with a lower number representing a darker colour (McGuire, 1992). Chroma (C) is the degree of departure from white towards the pure hue colour and is a measure of colour saturation, while hue angle (H) quantifies colour, where 0º= red/purple, 90º= yellow and 180º= bluish/ green (McGuire, 1992). Thai and Shewfelt (1990) found the calculation of hue angle and chroma to be a good measure of fruit peel colour as they relate better to human colour perception.

Colour charts, specific for each cultivar, may also be used to score the colour of each fruit. Jaeger *et al.* (2003) used commercial colour chips to measure the intensity of green and yellow to assess apple harvest maturity. Readings on the ENZA 1996 Braeburn chart were transformed into values on a 14-point scale anchored at 0 = ‘not green’ and 14 = ‘intensely green’ to asses green colour (Jaeger *et al*., 2003). While readings on the ENZA 1996 Gala/Royal Gala chart for yellow were transformed into values on a 20-point scale anchored at 0 = 'not yellow' and 20 = 'intensely yellow' (Jaeger *et al.*, 2003). Cronje (2014) assessed background colour by using the Colour Charts for Apples and Pears (Unifruco Research Services [Pty] Ltd.) with a scale of 0.5 to 5 (where 0.5=dark green, and 5=deep yellow).

4.2 Descriptive sensory analysis (DSA)

The Institute of Food Technologists (1975) defined sensory analysis as a scientific method used to evoke, measure, analyse and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing. The qualitative aspects of a product measured during sensory analysis include all aroma, appearance, flavour, texture, aftertaste and sound properties which distinguish it from others (Murray *et al.,* 2001).

Sensory judges quantify these product qualities in order to facilitate description of the perceived product attributes (Dzung *et al.*, 2005). The importance of sensory analysis is that it allows for the determination of the relationship between the chemical and descriptive sensory profile of a product (Murray *et al.,* 2001). It is a way to reduce risk and uncertainty in decision making during product development. Consumers buy a food product for a variety of reasons that could include nutrition, convenience, and image, but most importantly the sensory properties and sensory consistency. Sensory analysis should, therefore, be an integral part in defining and controlling product quality (Dzung *et al.*, 2005).

DSA requires a panel with some degree of training or orientation according to Murray *et al.* (2001) and Lawless and Heymann (2010) also state that this sensory technique necessitates a panel of judges trained for consistency and reproducibility. The training phase usually begins with the development of a common language that comprehensively and accurately describes the product attributes (Murray *et al.,* 2001). The specific sensory attributes of the product are then scored on a line scale and the data used to analyse the samples according to an experimental design, followed by analysis of variance (ANOVA) and appropriate multivariate statistical techniques (Lawless and Heymann, 2010).

In fruit research, trained sensory panels and the technique descriptive sensory analysis (Lawless and Heymann, 2010) are usually used to assess eating quality. Gatti *et al.* (2011) evaluated apples with a panel of 12 judges trained in the sensory analysis of fruit. Characteristics chosen on the basis of previous research done by

Predieri and Gatti (2009) were crispness, firmness, juiciness, sweetness, acidity, aroma and mealiness. Manning (2009) evaluating 11 pear genotypes in the Western Cape Province of South Africa employing a sensory panel of nine assessors, trained in the consensus method as described by Lawless and Heymann (2010) and also tested for consistency.

A 100 mm unstructured line scale was used for each attribute intensity analysis, the left side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity. To train the panel for sensory attributes, a sample from each pear genotype was used. The definitions used were similar to those described by Jaeger *et al.* (2003). The panel first agreed upon the scores for the sensory attributes of 'Bon Chrétien' before starting the assessment of the other genotypes. The flavour attributes of overall pear flavour, sweet taste, sour taste and astringency, as well as the texture attributes of, crunchiness, hardness, melt character, juiciness, mealiness and grittiness were evaluated.

Overall pear flavour is defined as the aromatics of a typical pear, sweet taste is the basic taste caused by characteristic sugars on the tongue while sour taste is the basic taste on the tongue caused by characteristic acids (Daillant-Spinnler *et al.*, 1996). Astringency is defined as the sensation of drying of the mouth and in the research done by Manning (2009) on pears, astringency was found to have a very negative effect on consumer preference. The texture attribute of crunchiness is defined as the noise generated when chewing with molars while hardness is the force required to compress the sample with molar teeth. Melt character is the melting of flesh in the mouth while juiciness is the amount of juice released by the sample while chewing (Daillant-Spinnler *et al.*, 1996). Mealiness is the texture of over-mature fruit recognised by a soft, dry pulp (Jaeger *et al.*, 2003) and characterised by low extractable juice content (Barreiro et al., 1998; Martin 2002) while grittiness refers to the presence of small hard particles in the fruit flesh that have a sandy texture between the teeth (Jaeger *et al.*, 2003). Mealiness is the key internal quality disorder associated with the sensory quality of 'Forelle' pears in South Africa (Carmichael, 2011; Crouch, 2011; Martin, 2002). 'Forelle' pears grown in South Africa for the European and UK market have a mandatory cold storage period of 12 weeks at -0.5 ˚C after harvest, as they are prone to astringency and mealiness after shorter storage durations. The 'Forelle' early market access programme (FEMA) has been researching the possibility of entering the European, UK and Middle Eastern markets by week 15, after only 4 - 6 weeks of cold storage. In order to do this while maintaining fruit eating quality, pears are left to ripen on the tree for 3 – 4 weeks longer after commercial harvest and subsequently treated with 1-methylcyclopropene (1-MCP; Smartfresh™, AgroFresh Inc., Rohm & Haas Company, Philadelphia, PA) to inhibit further ripening and softening. These fruit are then aimed at a target market that prefers crisp and sweet pears (Crouch and Bergman, 2013).

In a study aiming to quantify the sensory changes induced in pears by conventional cold storage and subsequent ripening at room temperature, Raffo *et al.* (2011) used descriptive sensory analysis as a tool. 'Bon Chrétien' pears were stored for 60 days at 0°C and then ripened at 20°C for 0, 1, 3 or 5 days followed by sensory evaluation using a trained panel. There were statistically significant differences in intensity of aroma, flavour, juiciness, firmness and melt character between pears that were ripened for different durations. The unripe fruit evaluated at room temperature were high in firmness and showed little taste, low flavour intensity and juiciness. After 5 days of ripening, pears were much lower in firmness and the aroma intensity was higher, but this was mainly due to the development of defective aromas such as alcohol and fermented. It was concluded that the pears attained their best sensory quality after ripening for 3 days at room temperature.

4.3 Consumer liking of fruit eating quality and appearance

In 2010, the European Union, along with partner universities, co-financed the 'ISAFruit' project in an effort to increase fruit consumption. This was done through a transdisciplinary approach that would lead to high quality produce from environmentally safe, sustainable methods (Wiersinga *et al.,* 2012). Based on a study of ten successful European fruit supply chains, it presents guidelines and identifies critical success factors (CSF) to the fruit industry for stimulating further development of consumer driven chains. One of these CSF's, and a basic requirement, is a strong focus on customers' needs and alignment to consumers' demands. As not all individuals in the fruit chain have direct contact with, or information about end consumers, they tend to focus on meeting the demand of their direct customers, assuming these have translated the end consumer demands into their requirements. It is therefore important to continue monitoring whether

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customers' requirements actually reflect consumers' preference to ensure the fruit industry supplies products that consumers want (Wiersinga *et al.,* 2012).

An effective approach to judging consumer preference for fruit quality is to have the final product evaluated by a representative sample of target consumers (MacFie, 1990; Predieri and Gatti, 2009). Consumers are usually asked to taste the product and then indicate their degree of liking on a nine-point hedonic scale that ranges from 1 (dislike extremely) to 9 (like extremely) (Lawless and Heymann, 2010).

Studies done on consumer acceptability of organic and cosmetically damaged apples by Yue *et al*. (2007) asked consumers about their willingness to purchase based on external appearance rather than their degree of liking for taste. The interviewees were presented with photographs of the six apples and then asked to decide how willing they would be to buy apples. They had five choices: very willing, somewhat willing, neutral, somewhat unwilling, or unwilling. After making the choice of willingness to buy for each of the apples pictured, the consumer was asked to answer several additional questions concerning regularity of apple purchase, previous gardening or purchase experience, and preferences for local production in their purchase decision.

The results show that consumers will pay a premium for organic production methods and for apples with low amounts of cosmetic damage. When there are 'too many' blemishes on the surface of organic apples, consumers would rather buy conventional ones with better appearance, even if the spots are merely a cosmetic problem. Behavioural variables such as experience growing fruit significantly affect the willingness to buy apples of different damage levels (Yue *et al*., 2007).

In assessing South African consumer preference of pears, Manning (2009) asked 150 consumers to complete standard questionnaires analysing their degree of liking for six genotypes. Questions covered the sensory analysis of peeled and unpeeled samples as well as analysing preference of appearance by including photographs of each pear. In addition, consumers were asked to describe their ideal pear. After tasting each sample the consumers were asked to indicate which term best described their attitude towards the product using the nine-point hedonic scale with categories ranging from 1 (dislike extremely) to 9 (like extremely) with 5 being neutral (neither like or dislike).

The research suggested that South African consumers like yellow, green and lightly coloured blushed pears and that pear flavour, sweet taste, melting character, juiciness and a soft texture were important sensory attributes while mealiness and hardness were the main negative attributes (Steyn *et al*., 2011). The findings were also consistent with international studies like that done by Jaeger *et al*. (2003), in a survey done in New Zealand to assess consumer preference of pears, which indicated high pear flavour, sweetness, melting texture and juiciness as the most preferred sensory attributes in European pears. In similar research done by Kappel *et al.* (1995) with 496 Canadian consumers, the ideal pear had a yellow colour, a low firmness and a sweet taste with slight sourness. Turner *et al.* (2005) got similar results with a study of 780 American consumers. Most participants preferred a sweet pear, with high pear flavour. Yellow was the colour of preference and a 'Bon Chrétien' shape was preferred (Turner *et al.* 2005). Among Italian consumers, preference for eating quality also correlates highly with aroma, sweetness and juiciness (Predieri *et al.* 2005).

Relating eating quality to consumer preference data requires a model that permits different preference patterns to be detected and incorporated. The use of preference mapping for this task has been promoted (Jaeger *et al.,* 2003). Preference mapping projects a series of consumer scores of the same set of samples onto a set of preference dimensions that represent the differences among the samples and a set of vectors, one for each consumer, that show the individual directions of increasing preference. This model is favoured by market-led organizations, and the correlations of sensory attributes given by laboratory panels can be superimposed onto this space (MacFie, 1990).

5. Summary

South Africa produces 3% of the global pear output and pears make up 16% of the local deciduous fruit industry (HORTGRO, 2015). In order to stay competitive on overseas markets and grow the local market, it is important to produce top quality fruit that appeals to consumers. It has therefore been suggested that quality should be defined from the consumer's perspective as the final user of the product (Predieri *et al*., 2005). When referring to fresh produce, quality refers to sensory properties

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like appearance, texture, taste and aroma as well as nutritive values and chemical constituents (Abbott, 1999).

Since the initial judgement of a fruit's quality is made on appearance (Abbott, 1999) i.e. colour and freedom from blemishes can be viewed as some of the most important characteristics of food (Lawless and Heymann, 1999). Once fruit is bought, however, the sensory characteristics of flavour, texture and aroma becomes important in the decision to repurchase. Sensory analysis is therefore becoming very important in supporting breeding and cultivar selection (Hampson *et al*., 2000).

Trained panels measure the sensory characteristics of the product i.e. juiciness, sweetness, astringency, sourness, bitterness and texture (Kappel *et al*., 1995), while consumer panels are asked to indicate which term best described their attitude towards the product using the nine-point hedonic scale (Jaeger *et al*. 2003). Preference mapping is a multivariate technique that is extensively used to relate consumer preferences to product characteristics. It also allows identification of the key sensory attributes that drive consumer preference (Daillant-Spinnler *et al*., 1996; Thybo *et al*., 2003). It constitutes a group of statistical techniques that analyse preference data by taking individual differences in consumers' preferences into account (Harker *et al*., 2002).

Finding correlations between instrumental measurements and sensory evaluation would be very useful as it will simplify the analysis process. However, using instruments to measure the physical and chemical properties of a product does not mimic the eating process and therefore the data do not necessarily relate to the eating quality (MacFie, 1990). Kappel (1995), however, concluded that the TSS:TA ratio could be a useful indicator of quality in pears.

Understanding consumer preference will enable the pear industry to provide the best product to the consumers in such a way that it leads to the largest possible needs-satisfaction of the community as a whole (Lucas *et al*, 1979).

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Paper 1: Preference of Western Cape Province consumers of different ethnicities for pear eating quality and appearance

Abstract

Understanding consumer preference for pear taste and appearance puts the industry in a better position to maximise profits and reduce the considerable waste of fruit produced each year but never consumed as it did not find the right buyers. To identify the drivers of preference and possible consumer groupings, 10 pear cultivars were evaluated. The intention was to select cultivars in such a way that a wide range of pear characteristics were offered so that the main drivers of liking could be identified – cultivars were not compared *per se*. A trained panel assessed the sensory attributes of each and then 421 consumers from different age, gender and ethnic groups did a taste test and filled in questionnaires recording their preferences for taste and appearance. Instrumental measurements were also taken of each cultivar and correlations looked for between variables. The data indicate that the majority of consumers of all three ethnic groups, genders and ages in the Western Cape, showed a preference for pears with a distinct pear flavour, a sweet taste, a fair amount of acid, soft, juicy flesh with melt character, and a yellow or pale green peel colour with a typical pear shape (elongate-concave). Astringency, sourness and grittiness had a negative effect on consumer preference. Two clusters of consumers were identified that have similar preferences. For these clusters no obvious compositional differences were found in terms of gender, ethnicity or age for eating quality and appearance. Overall, group 1 indicated a liking for a wider range of cultivars while group 2 had a small selection of cultivars that they really liked for appearance and eating quality. Group 2 seemed more familiar with pears in general and showed a definite preference for the cultivars they were familiar with and liked. In contrast, group 1 likes and dislikes were not as clearly defined. The data indicated that most consumers did not prefer the appearance of bi-coloured pears; in fact it scored relatively low for appearance, although it was rated higher by the white ethnic group than by the other two groups, suggesting greater familiarity of white consumers with these fruit. The round, russeted appearance of the only Asian pear included in the study was disliked by consumers. Marketing of Asian pears or hybrids with non-traditional shapes and appearances may require branding under another name so not to clash with consumer expectations with regards to pear taste and appearance.

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Introduction

The pear industry in South Africa, with its balanced mix of cultivars and markets, slowly continues to expand (Belrose Inc., 2015). South Africa produces 3% (413614 tons) of the global pear production of which 15% (48535 tons) are sold on the local fresh market, 48% (203660 tons) are exported, 35% (149618 tons) are processed and 2% (11800 tons) are dried (HORTGRO, 2014). In order to stay competitive on overseas markets, but also grow the local market, it is important to produce top quality fruit that appeals to consumers.

Fruit quality is a multi-criteria concept that is not easily defined as it is a combination of both physical and chemical attributes (Kader, 1999). It can also mean different things to different people within the production chain. Farmers are interested in high yield and good appearance, as well as storage potential to ensure that fruit arrive in good condition after being shipped to different markets. Good appearance and a long shelf-life are important to wholesalers and retail marketers, while consumers judge fresh fruit on the basis of appearance first (Abbott, 1999). It has been suggested that quality should be defined from the consumer's perspective as the final user of the product (Predieri *et al.*, 2005).

External factors such as peel colour and blemishes are some of the most important characteristics of fruit according to Lawless and Heymann (2010) and can influence the initial reaction of a consumer to fresh fruit. Cultivar developers, however, have to keep in mind that the ultimate judgement will only be made once the fruit has been tasted (Kingston, 1991; Echer Zerbini, 2002; Gamble *et al.,* 2006). Then the sensory characteristics of aroma, flavour and texture become important in the decision to repurchase (Kader, 1999; Crisosto *et al.*, 2003). Fruit quality is an evolving variable that changes over time as expectations of consumers change (Harker *et al.*, 2002). Hence, it is of great importance to assess consumer preference for eating quality and keep the main drivers of preference in mind during the breeding of new cultivars. Sensory, as well as consumer analysis, are therefore becoming very important in supporting breeding and cultivar selection (Hampson *et al.,* 2000).

Due to differences in traditional food habits and availability of regional flavour sources, the degree of liking of food differs across regions (Pangborn *et al.*, 1988). South Africa is a developing country with a diverse socio-economic and multicultural society where white consumers' eating patterns are generally described as Western, but are perceived to differ from those of black consumers (Viljoen and Gericke, 2001). Van der Merwe (2013) found differences in the preferences of white, coloured and black consumers in the Stellenbosch region of the Western Cape province of South Africa for apple appearance and taste.

Black and coloured consumers generally preferred sweeter fruit than white consumers. Although ethnicity is one of the key determinants of food choice (Prescott and Bell, 1995), its effect on food preference is poorly understood (Pangborn *et al.*, 1988). Limited information is available on the eating habits and food preferences of the different ethnic groups in South Africa (Viljoen and Gericke, 2001). Previous research by Manning (2009) tried to establish whether the preferences of South African consumers for pear eating quality and appearance are in agreement with those of consumers from Europe. Since only white consumers were included in that research, Manning (2009) suggested that a follow-up study to assess preference among different ethnic groups in South Africa may provide further valuable data to cultivar developers and marketers.

This study aimed to fill that gap and determine the differences, if any, in preference for pear eating quality and appearance amongst ethnic groups in the Western Cape region of South Africa. In addition, differences based on age group and gender was also investigated. Understanding consumer preference will enable the pear industry to provide the best product to the right consumers.

Materials and methods

Plant material

Ten pear genotypes were selected for this study, to represent a diversity of pear characteristics such as peel colour, shape and eating quality. Nine European (*Pyrus communis* L.) and one Asian pear (*P. pyrifolia* (Burm.) Nak.) were included. Eight of these are established cultivars, while two are seedling selections. The commercial cultivars used were yellow Bon Chretien, green Packham's Triumph and Doyenné du Comice (here after shortened to Comice), blushed Cheeky and Forelle, green-russeted Abate Fetel and Hosui, and full-red Red D'Anjou. The experimental selections were full-red P 04-21 and mottled green and slightly blushed 3D-37-38 (Figure 1).

The pears were sourced from two pack houses in the Western Cape, South Africa, viz. Wallet fruit, Ceres (latitude: 33˚23'S, longitude: 19˚19'E) and ARC Bien Donne, Stellenbosch (latitude 33˚58'S, longitude: 18˚50'E). Pears were harvested within their commercial harvest window between 6-8 kg as measured using a penetrometer (Fruit Texture Analyser; GUSS Manufacturing (Pty) Ltd., Strand, South Africa) fitted with a 7.9 mm diameter probe. Two equatorial readings were taken on opposite, pared sides of each pear. Bon Chretien, however, was left on the tree a month longer than usual due to the specific farmer's preference. All fruit were harvested, randomly from any position on the trees, between the middle of January to mid-February. The harvest maturity data and the harvest dates of the fruit were unfortunately not available from the ARC. We again have to emphasize that our intention was to obtain a wide range of pear eating quality characteristics and not to present consumers with fruit of optimum eating quality for all cultivars. After harvest the pears were kept in regular atmosphere (RA) cold storage at -0.5 ˚C. Seven days prior to each assessment date, pears were randomly selected from each genotype and removed from cold storage to ripen at room temperature. Sensory descriptive analyses were performed on 18 April and 20 April, consumer analyses on 21 April and 23 April and instrumental analyses on 24 April 2012.

Experimental design

Hundred (N=100) fruit from each cultivar were harvested. Of these, three fruit per cultivar were used for photographs (taken after RA cold storage and after ripening for seven days at 20 ºC) with one photograph of each cultivar selected for inclusion in the consumer questionnaire, five fruit per treatment for physicochemical analyses and firmness measurements (one fruit per replicate), four (one per replicate) for descriptive sensory analysis and 70 per cultivar for the consumer panel test.

All fruit were kept in the cold storage until seven days before each analysis date, when it was allowed to ripen at room temperature (24 ºC) at the Department of Horticultural Science, Stellenbosch University, South Africa.

Physicochemical measurements

Instrumental analyses were conducted on 24 April 2012 using five fruit from each cultivar. Fruit firmness (kg) was determined as the maximum force required to push an 7.9 mm diameter probe with a convex tip into the flesh, after peeling two equatorial sites, using a motorised penetrometer (Fruit Texture Analyser; GUSS manufacturing (Pty) Ltd., Strand, South Africa).

Percentage dry matter concentration (DMC) was determined by weighing a fresh pear sample and oven drying the pear sample over a period of 72 hours at 45 ℃. The pear sample was weighed, returned to the oven for another 24 hours and re-weighed to ensure that all the moisture had evaporated. The percentage DMC was calculated as dry weight as a percentage of fresh weight.

Slices of pear were placed in a juice extractor and the juice from each sample was used to determine the total soluble solids (TSS) concentration with a digital refractometer (TSS 0-32%, Model N1, Atago, Tokyo, Japan) and titratable acidity (TA) using an automated titrator (Tritino 719S and Sample Changer; Metrohm Ltd., Herisau, Switzerland) by titrating 10 g of juice from each pear with 0.1 M NaOH to an endpoint of 8.2. TA results were expressed as percentage malic acid. The TSS:TA ratio was calculated for all samples. Average values per treatment were calculated and used for further statistical analysis. As no mealiness was identified in any samples during the descriptive sensory analysis, no instrumental test for mealiness was conducted.

Descriptive sensory analysis

The testing phase of descriptive sensory analysis (DSA) was carried out on 18 and 20 April 2012 in the sensory research laboratory at the Department Food Science, University of Stellenbosch, South Africa. All eight panellists had prior experience in DSA and were familiar with the sensory attributes of the fresh pear product. Prior to the testing phase, the panel of judges received extensive training using the consensus method to develop and define descriptors (Lawless and Heymann, 2010). The definitions used for the sensory attributes (Table 1) were similar to those used by Daillant-Spinnler *et al*. (1996). Four training sessions were held, approximately 50 min per session. During each training session the panel members were exposed to all ten cultivars of pear samples. A 100 mm unstructured line scale was used to rate each attribute, where the left side of the scale corresponds to the lowest intensity and the right hand side corresponds to the highest intensity (Lawless and Heymann, 2010).

For the test phase of descriptive sensory analysis a complete randomised design was used, i.e. ten treatments (cultivars) and four replicates. Panellists were seated individually at sensory booths that were light and temperature controlled (21 °C) and fitted with the data capturing software programme Compusense *five* (Compusense®, Guelph, Canada). Each judge received an unpeeled pear slice, cut lengthwise from the same pear; hence the sample size was an eighth of a pear. Each of the ten pear samples was coded with a three-digit random code and presented on petri dishes in a completely randomised order. A total of four replications (ten treatments per replication) were evaluated over four sessions, two replicate sessions per day. The judges were asked to peel the pears and for this purpose a sharp knife was provided. Distilled water and unsalted fat free biscuits (Woolworths, Cape Town, South Africa) were provided as palette cleansers between samples.

Consumer preference testing

Consumer preference tests were conducted in the Lombardi building, Stellenbosch University on 21 April and in the Langenhoven Student Centre, Stellenbosch University, South Africa on 23 and 24 April 2012. On each of the assessment days, approximately 150 consumers were asked to taste samples of all 10 cultivars and complete questionnaires comprised of three sections viz.: 1) taste tests measuring degree of liking of pear eating quality; 2) photographs to ascertain degree of liking of pear appearance and 3) perceptual assessment of ideal pear characteristics and degree of liking of fresh fruit in general. For the first part of the questionnaire consumers were given a tray with 10 peeled samples consisting of an eighth of a pear per cultivar. Each pear sample was coded with a three-digit random code and presented on Petri dishes in a complete randomised order. Consumers were asked to indicate their degree of liking of each sample's eating quality using the nine-point hedonic scale where 1 indicates *'dislike extremely'*, 5 being neutral, i.e. *'neither like nor dislike'*, and 9 *'like extremely'*. The second part of the questionnaire consisted of full colour photographs of pre-ripened fruit taken on 16 April 2012 by Stellenbosch University photographic services (Figure 1). The pictures were taken after RA cold storage and after ripening for seven days at 20 ºC. Once again, the nine-point hedonic scale was used to assess preference for appearance.

Statistical procedures

The purpose of the consumer study was to analyse the preference of Western Cape consumers of different ethnic, age and gender groups for the appearance and eating quality of pears as described above. Instrumental and sensory data were included in the statistical analysis to serve as an external data set to further explain the intrinsic factors that drive consumers' pear preferences.

Physicochemical analysis data for firmness, DMC, TSS, TA and TSS:TA were subjected to one-way analysis of variance (ANOVA) by general linear models (GLM) using Statistica version 12 (StatSoft Inc., Tulsa, OK) with cultivar as main effect. Student's t-Least

Significant Difference was calculated at the 5% significance level to compare treatment means. The Shapiro-Wilk test was performed on the residuals to test for non-normality (Shapiro & Wilk, 1965). If non-normality was significant (P≤0.05) and caused by scewness, the outliers were identified and removed until the data were normally or symmetrically distributed. The final analysis of variance (ANOVA) was performed after the pre-processing procedures had taken place.

The sensory data for each attribute were subjected to a three factor analysis of variance (ANOVA) using cultivar, panellists and replications as main effects No significant interaction (P≤0.05) was found, indicating that the mean scores gave a reliable estimate of the sensory attributes of the samples. Cultivar attributes were therefore averaged across replicates and panellists.

For consumer preference data, a complete randomised design was used. ANOVA was performed on the consumer data to establish if there was a difference in the consumer preference for pears with regard to eating quality and appearance for different ethnic, age and gender groups using Statistica version 12 (StatSoft Inc., Tulsa, OK).

To identify potential consumer groups with similar preferences, Ward's hierarchical cluster analysis was performed on the residual data. Having identified two main groups from the dendrogram, K-means clustering was then performed on the two groups. Establishing that there was a good correlation between the two methods of clustering, it was decided to continue with K-means clustering.

Multivariate statistical analysis was employed (XLStat, Addinsoft, France) to investigate the possible relationships between physicochemical data, descriptive sensory data and consumer preference data, e.g. Principal Component Analysis (PCA). Principal Component Analysis (PCA) was carried out to identify variables that associate with certain treatments (Rencher, 2002). PCA is a projection method that assists one to visualize all the information in a data table; it provides a tool to find patterns and relationships between samples and several variables simultaneously. XLStat software (Addinsoft, France) was used to perform Pearson's correlation between sensory and physicochemical measurements.

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Results

For the purpose of this part of the study and in order to refrain from vague terms for reporting, "*preference for eating quality*" indicates a consumer's degree of liking for the overall texture and flavour of pears, where the term "flavour" includes sweet taste, sour taste, as well as pear aroma (Rowan *et al.*, 2009). "*Preference for appearance*" indicates how consumers liked the overall appearance of the fruit. For the sake of readability and brevity, only the most important differences in sensory and instrumental sample attributes will be reported.

Physicochemical measurements

Firmness

'Forelle' with a mean firmness of 3.9 kg, 'Red D'Anjou' at 3.6 kg, 'Packham's Triumph' at 3.5 kg along with 'Hosui' at 3.5 kg, and 'Abate Fetel' at 3.3 kg, were the firmest fruit and did not differ significantly from each other (Table 2). 'Cheeky' at 3.0 kg and '3D-37-38' at 2.9 kg were less firm than 'Forelle', but did not differ from 'P 04-21' at 2.8 kg, 'Packham's Triumph', 'Hosui' or 'Abate Fetel', and 'Bon Chretien' at 2.3 kg. 'Comice' had the lowest firmness overall at 1.8 kg, but was not significantly different from 'Bon Chretien'.

Total soluble solids (TSS)

'Forelle' at 16.6 ºBrix, 'Bon Chretien' at 16.5 ºBrix, 'Comice' at 15.8 ºBrix and 'Hosui' at 15.6 ºBrix had the highest TSS concentrations and did not differ significantly from each other (Table 2). 3D-37-38' and 'Abate Fetel' at 14.3 ºBrix, and 'Packham's Triumph' at 13.2 ºBrix formed a second group with lower TSS levels. 'Cheeky' at 12.8 ºBrix did not differ significantly from 'Packham's Triumph'. 'Red D'Anjou' at 10.4 ºBrix and 'P 04-21' at 9.3 ºBrix with the lowest TSS concentrations did not differ significantly.

Titratable acidity (TA)

'Comice' and '3D-37-38' at 0.28%, 'Bon Chretien' at 0.27% and 'Packham's Triumph' at 0.23% malic acid had the highest TA and did not differ significantly from each other (Table 2). A middle group was formed by 'Red D'Anjou' (0.21% malic acid), 'Forelle' and 'Abate Fetel' (both 0.20%), 'Hosui' (0.18%) and 'Cheeky' (0.17%). Of these, only 'Cheeky' differed

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significantly from 'Packham's Triumph'. 'P 04-21' at 0.15% malic acid had the lowest TA, but it did not differ significantly from 'Forelle', 'Abate Fetel', 'Hosui' or 'Cheeky'.

TSS:TA

'Hosui' (87), 'Forelle' (86), 'Cheeky' (75) and 'Abate Fetel' (70) had the highest TSS:TA ratios and did not significantly differ from each other (Table 2). 'P04-21' (62) did not differ from Cheeky and Abate Fetel, but also not from 'Packham's Triumph' (60), 'Comice' (64) and 'Bon Chretien' (63). 'Red D'Anjou' (50) and '3D-37-38' (52) had the lowest for TSS:TA and did not differ from each other, but also did not differ significantly from the previous group.

Dry mass concentration (DMC)

'Abate Fetel' at 0.20, 'Comice', 'Bon Chretien' and 'Forelle' at 0.19, '3D-37-38' at 0.18 and 'Hosui' at 0.17 did not differ significantly in DMC (Table 2). 'Packham's Triumph' and 'Cheeky' with a mean of 0.16 scored lower than the previous group for DMC, but did not differ significantly from 'Hosui' or '3D-37-38'. 'Red D'Anjou' at 0.13 did not differ significantly from 'Packham's Triumph' or 'Cheeky' and also did not differ significantly from the lowest scoring pear for this attribute 'P04-21' that had a mean of 0.12.

Mealiness

In this study no discernible mealiness was found in any of the samples.

Sensory attributes

Overall pear flavour

'Bon Chretien' had prominent pear flavour and scored the highest for this attribute (mean value of 75 on a 100-point scale) (Table 3). 'Comice' scored slightly lower (66), but did not differ significantly from 'Abate Fetel' (59) or 'Cheeky' (56). 'Forelle' (48) scored significantly lower than 'Comice', but did not differ from 'Abate Fetel' or 'Cheeky'. 'Hosui' (40) and 'Red D'Anjou' (38) had low pear flavour and did not differ significantly from each other. 'Packham's Triumph' (37), P04-21(36) and 3D-37-38 (32) scored lowest for overall pear flavour.

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Sweet taste

’Bon Chretien’ scored the highest for sweet taste (63), but not significantly different from ‘Comice’ (58) (Table 3). ‘Abate Fetel’ (54) did not differ significantly from ‘Comice’. ‘Hosui’, ‘Cheeky’, and ‘Forelle’ all scored just below 50 for sweet taste and did not differ significantly from ‘Abate Fetel’. ‘Packham’s Triumph’, ‘P04-21’, ‘Red D’Anjou’ and ‘3D-37-38 scored below 40 for sweet taste did not differ significantly from each other.

Sour taste

The range of sour taste was low for all cultivars with mean scores ranging between 11 and 20 as analysed on the 100-point scale (Table 3). ‘Packham’s Triumph’ (20) and ‘3D-37-38’ (19) scored the highest for sour taste. ‘Bon Chretien’ and ‘Forelle’ both had mean scores of 15. ‘Red D’Anjou’ (13) did not differ significantly from the latter two cultivars. ‘Hosui’, ‘Comice’, ‘P 04-21’, ‘Cheeky’, and ‘Abate Fetel’ formed a group that scored very low in sour taste and did not differ significantly from ‘Red D’Anjou’.

Astringency with peel

The 44 points that 3D-37-38 scored for astringency was significantly higher than for all the other cultivars (Table 3). Packham’s Triumph scored 18, followed by all the other cultivars that scored below 10. The score below 10 represents a degree of astringency that is barely perceptible.

Hardness

‘Packham’s Triumph’ (44), ‘Forelle’ (42), ‘Abate Fetel’ (41), ‘Red D’Anjou’ (40) and ‘Hosui’ (38), did not differ in hardness (Table 3). ‘P 04-21’ (34) did not differ from ‘Hosui’, Red D’Anjou’ or ‘Abate Fetel’ and also not from ‘Cheeky’ (32) and ‘3D-37-38’ (28). ‘Bon Chretien’ (26) did not differ from ‘Cheeky’ (32) or ‘3D-37-38’ (28), but also not from ‘Comice’ (20) that was significantly softer than all the other cultivars.

Melt character

The highest levels of melt character were found in ‘Comice’ (60) and ‘Bon Chretien’ (52), which did not differ from each other, but had significantly higher levels of this attribute than

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all other cultivars (Table 3). ‘Cheeky’ (33), ‘Hosui’ (32), ‘Abate Fetel’ (28), ‘3D-37-38’ (26) and ‘P 04-21’ (24) formed a middle group with low levels of melt character, while the lowest scores were given to ‘Red D’Anjou’ (22), ‘Forelle’ (18) and ‘Packham’s Triumph’ at (14) that did not differ from each other significantly. ‘Packham’s Triumph’, however, did not differ significantly from ‘P 04-21’, ‘Red D’Anjou’ did not differ significantly from ‘Hosui’, ‘3D-37-38’ or ‘Abate Fetel’ and ‘Forelle’ did not differ significantly from ‘3D-37-38’ or ‘Abate Fetel’.

Juiciness

‘Comice’ (60), ‘Hosui’ (59), ‘Bon Chretien’ (58), and ‘Cheeky’ (55) did not differ significantly from each other and scored high for this characteristic, illustrating a distinct degree of juiciness when consuming the product. ‘P 04-21’ (52), ‘Abate Fetel’ (51) and ‘Red D’Anjou’ (47) formed the middle group for juiciness (Table 3). ‘P 04-21’ did, however, not differ significantly from ‘Bon Chretien’ or ‘Cheeky’ and ‘Abate Fetel’ did not differ significantly from ‘Cheeky’. ‘Packham’s Triumph’ (45), ‘Forelle’ (45) and ‘3D-37-38’ (44) had the lowest scores for juiciness; these three treatments showed a perceptible reduction in juiciness.

Grittiness

‘3D-37-38’ (41), ‘Hosui’ (37) and ‘P 04-21’ (36) and ‘Cheeky’ (36) showed the highest mean scores for grittiness (Table 3). These four treatments did not differ significantly from each other. All the other samples had lower scores for grittiness, i.e. ranging between 28 and 33.

Consumer preference of total group of consumers

Consumer socio-demographic information

The black, white and coloured consumer groups respectively constituted 135 (32%), 136 (32%) and 150 (36%) of the total consumer group (N=421) while 293 (70%) consumers were female and 128 (30%) male. With regard to age, 150 consumers (36%) were between 18 - 25 years of age, 60 (14 %) between 26 - 30 years, 82 (19 %) between 31 - 40 and 129 (31 %) were 41 years and older.

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Consumer preference for eating quality

For the purpose of this part of the study and in order to refrain from vague terms for reporting, "*preference for eating quality*" indicates a consumer's degree of liking for the overall texture and flavour of pears, where the term "flavour" includes sweet taste, sour taste, as well as pear aroma (Rowan *et al.*, 2009).

To assess consumer preference for eating quality, the consumers had to taste pear samples and score the liking of the overall eating quality, i.e. flavour, texture and taste on the nine-point hedonic scale ranging from '*dislike extremely*' (1) to '*like extremely*' (9).

'Comice' at 7.3 and 'Bon Chretien' at 7.0 scored highest for liking of eating quality and did not differ significantly from each other (Table 4). They were followed by 'Cheeky' at 6.7 and then 'Abate Fetel' and 'Packham's Triumph' at 6.0 and 'Forelle' at 5.7, with the last three cultivars not differing significantly. 'Hosui' scored 5.3, 'P 04-21' scored 4.5 and 'Red D'Anjou' scored 4.3, while '3D-37-38' scored significantly lower at 4.0.

Ethnicity generally did not seem to affect preference for eating quality except for the lower score of white consumers for '3D-37-38' compared to black and coloured consumers and the greater liking of black consumers for 'Hosui' compared to coloured consumers (Figure 2). Gender also in general did not affect preference for eating quality except for the greater liking of male consumers for '3D-37-38' (Figure 3). Age had no effect on preference for eating quality (Figure 4).

Consumer preference for appearance

To assess consumer preference for appearance, consumers viewed life-size photographs (Figure 1) of the respective cultivars and scored their preferences for the overall appearance of the respective cultivars using the nine-point hedonic scale. 'Bon Chretien' (7.3) and 'Packham's Triumph' (7.2) received the highest mean scores and did not differ statistically from each other followed by '3D-37-38' (6.4), 'Abate Fetel' (6.1) and 'P04-21' (6.1), also not significantly different from each other (Table 4, Figure 1). 'Cheeky' and 'Forelle' with mean scores of around 6 did not differ from each other. 'Red D'Anjou' and 'Comice' fell in the neutral category, '*neither like nor dislike*', and the Asian pear 'Hosui' received the lowest liking score (4.8) indicating a slight dislike. Consumer ethnicity, gender and age significantly affected preference for the appearance of pears (Figure 5 to 7). White consumers liked '3D-37-38' and 'Hosui' less than coloured consumers, coloured consumers liked 'Abate Fetel' more than black consumers, white consumers liked 'Forelle'

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better than other consumers and 'P 04-21' better than black consumers (Figure 5). Consumers of all three ethnic groups showed a high liking for 'Packham's Triumph' while the high average liking score for 'Bon Chretien' is mostly due to the high preference of coloured consumers for the appearance of this cultivar.

There were only two instances where gender differences were observed with regard to preference for appearance. 'Bon Chretien' and 'Packham's Triumph' scored the highest overall but were also scored significantly higher by females than by males (Figure 6).

While the different age groups followed a similar trend in their liking of the appearance of the different pear cultivars, there were a few instances where preferences diverged (Figure 7). The youngest age group (18-25 years old) scored most pears significantly lower than the other age groups, with the exception of 'Forelle', 'P 04-21', 'Red D'Anjou' and 'Packham's Triumph', which they scored similar to older consumers. 'Forelle' and 'P 04-21' in particular, showed no significant differences between groups. 'Bon Chretien' and 'Packham's Triumph' had the highest scores for appearance for all age groups.

Multivariate associations of attributes and treatments

Physiochemical drivers of sensory quality of pears

To determine instrumental drivers of sensory quality and significant correlations between attributes, principal component analysis (PCA) were conducted (Figure 8). Significant Pearson correlations between the sensory and instrumental attributes are shown in Table 5. Observations that lie close to each other on the PCA plot signify a positive correlation while a negative correlation is indicated if they lie on opposite sides of the map. The PCA plot explained 68% of the variation between cultivars. PC1 and PC2 explained 46% and 22% of the total variability in the data, respectively (Figure 8). On the right side of PC1 the instrumental measurement of TSS showed a positive correlation with the sensory attribute of sweet taste ($r=0.684$; $P\leq0.05$) while DMC also correlated positively with sweet taste ($r=0.692$) and TSS ($r=0.895$). The sensory attribute of pear flavour correlated strongly with sweet taste ($r=0.940$), melt character ($r=0.787$) and to a lesser extent with juiciness ($r=0.641$). On the left side of PC1 the attribute instrumental firmness correlated strongly with the sensory attribute hardness ($r=0.933$) and strongly negatively with melt character (-0.875), while the sensory attributes of grittiness and astringency with peel also correlated with each other ($r=0.674$). Juiciness correlated negatively with sour taste ($r=-0.661$),

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astringency with peel (r=-0.513), hardness (r=-0.570) as well as the instrumental measurement of firmness (r=-0.626).

Sensory drivers of consumer preference of pears

The sensory drivers of consumer liking are identified in Table 5. Consumer preference for eating quality showed a correlation with the sensory attributes of overall pear flavour (r=0.867), sweet taste (r=0.827) and melt character (r=0.656), and a negative correlation with grittiness (r = -0.607) and astringency (r = -0.523). Figure 9 illustrates where consumer liking for eating quality, as well as, consumer liking for appearance lies in relation to the different cultivars. There was no correlation between consumer liking for eating quality and consumer liking for appearance (r = 0.159). Bon Chretien was the only cultivar that scored high for both appearance and eating quality. The classical pear shape (pyriform) of 'Bon Chretien' and 'Packham's Triumph' correlated with consumer preference for appearance while 'Comice', 'Bon Chretien' and to a lesser extent 'Cheeky' clustered around consumer preference for eating quality. 'Hosui', 'Forelle', Red D'Anjou', P04-21 did not correlate with either consumer's preference for eating quality or appearance.

Cluster analysis of consumer preferences

Cluster analysis of pear eating quality preferences

K-means clustering was used to identify potential consumer groups that have similar pear eating quality preferences. The total group of consumers could again be divided into two segments of consumers differing in degree of liking of pear eating quality (Figure 10).

In terms of the composition of the consumer clusters identified, group 1 consisted of 231 (55 %) consumers while group 2 had 190 (45 %). In terms of gender differences, group 1 consisted of 150 (65%) female and 81 (35%) male consumers, while group 2 included 143 (75%) females and 47 (25%) males (Figure 11). Hence, females were overrepresented and males underrepresented in group 2 compared to group 1.

In terms of ethnicity group 1 consisted of 66 (29%) white, 81 (35%) coloured and 84 (36%) black consumers, while group 2 had 70 (37%) white, 70 (37%) coloured and 50 (26%) black consumers (Figure 12). Ethnic differences between groups were not statistically significant (p=0.0595) although it seems that group 1 contained relatively fewer white and more black consumers, while the reverse is true for group 2.

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There was no significant difference in the distribution of age groups between the two consumer groups (p=0.59). In group 1, 83 people (36%) were 18 - 25 years of age, 31 (13 %) between 26 - 30 years, 41 (18 %) between 31 - 40 and 76 (33 %) were 41 years and older. In group 2, 67 people (35%) were 18 - 25 years of age, 29 (15 %) between 26 - 30 years, 41 (22 %) between 31 - 40 and 53 (28 %) were 41 years and older.

The mean liking scores of groups 1 and 2 for eating quality of the different cultivars are depicted in Figure 13. Group 1 rated all the cultivars between 5 and 7 on the 9-point hedonic scale while group 2 used a wider range of the scale and scored pears between just above 2.5 to just below 8 for eating quality preference. Group 1 consumers scored 'Comice' highest, followed by 'Bon Chretien', 'Cheeky', 'Forelle', 'Hosui' and 'Packham's Triumph' while 'Abate Fetel' was not significantly different from the last four pears. These consumers showed the lowest liking for '3D-37-38', 'P 04-21' and 'Red D'Anjou'. Group 2 gave 'Comice' and 'Bon Chretien' the highest overall scores followed by 'Cheeky', with intermediate scores given for 'Abate Fetel' and 'Packham's Triumph', which they liked equally followed by 'Forelle'. Their dislike for the remaining pears increased in order from 'Hosui' to 'P 04-21', 'Red D'Anjou' and lastly '3D-37-38'.

There were significant differences between the groups for every cultivar evaluated. Group 2 showed a higher preference for 'Comice', 'Bon Chretien' and 'Cheeky' and a lower preference for all the other cultivars.

Cluster analysis of pear appearance preferences

Cluster analysis of the liking scores for pear appearance was conducted in a similar fashion as that explained in the previous section. Based on the preferences for pear appearance, two clusters of consumers were again identified (Figure 14) with 257 (61%) of consumers in group 1 and 162 (39%) in group 2. In terms of gender, group 1 consisted of 170 (66%) female and 87 (34%) male consumers, while group 2 consisted of 121 (75%) female and 41 (25%) male (Figure 15). There were no significant differences in gender composition between group 1 and 2 (p=0.062).

In terms of ethnicity (Figure 16), group 1 consisted of 95 (37%) white, 88 (34%) coloured and 74 (29%) black consumers, while group 2 had 40 (25%) white, 62 (38%) coloured and 60 (37%) black consumers. Ethnic differences between groups were statistically significant (p=0.0255), with group 1 having more white and fewer black consumers than group 2, while there were also slightly fewer coloured consumers in group 1.

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Group 1 rated 'Bon Chretien', 'Cheeky', 'Forelle', 'P04-21', 'Packham's' and 'Red D'Anjou' the highest for appearance (Figure 17). All these cultivars scored between 6.5 and 7.5 on the hedonic scale. '3D-37-38' and 'Abate Fetel' scored between 6 and 6.5, while 'Comice' and 'Hosui' with a score of just above neutral 5 had the lowest mean scores for appearance. Group 2 scored 'Bon Chretien' and 'Packham's' the highest with 7.5 to just over 8, indicating that both groups preferred the appearance of 'Bon Chretien' and 'Packham's' overall. The two groups also agreed on the appearance of '3D-37-38' and 'Abate Fetel', as both groups scored them between 6 and 6.5. The groups differed, however, in their scoring of the other cultivars. Group 2 scored 'Cheeky', 'Comice', 'Forelle' and 'P04-21', just above and below the neutral hedonic score, 5 indicating 'neither *dislike nor like',* while group 1 rated 'Cheeky', 'Forelle','P04-21' and 'Red D'Anjou' as highly as 'Bon Chretien' and 'Packham's'. Group 2 scored two cultivars, 'Hosui' and 'Red D'Anjou' below 4 with a '*dislike slightly*' score. 'Hosui' was thus rated low by both groups.

There was no significant difference in the distribution of age groups between the two consumer groups (p=0.59). In group 1, 83 people (36%) were 18 - 25 years of age, 31 (13 %) between 26 - 30 years, 41 (18 %) between 31 - 40 and 76 (33 %) were 41 years and older. In group 2, 67 people (35%) were 18 - 25 years of age, 29 (15 %) between 26 - 30 years, 41 (22 %) between 31 - 40 and 53 (28 %) were 41 years and older.

Discussion

Different pear cultivars were selected and harvested and stored differently to provide a wide range of pear characteristics from which the drivers of liking of pear eating quality and appearance could be identified through descriptive sensory analysis and consumer testing. It is important to note that cultivars were not compared *per se* and as they were not all eating ripe, some of these pears e.g. Forelle may attain a much higher score when at optimum maturity as illustrated in the study done by Cronje (2014). This discussion will therefore focus on the characteristics present or absent in the most preferred pears that could then be used to select new cultivars, as well as help develop strategies that could provide the consumer with the best possible eating experience. The most prominent characteristics of the least liked pears will also be discussed. We unfortunately do not have the harvest maturities or harvest dates of the pears, which would have allowed contextualization of the eating quality attributes of the pears used in the study

When we investigated the physiochemical composition of the two pears that received the highest scores for eating quality, viz., ‘Comice’ and ‘Bon Chretien’, it is apparent that they had the lowest firmness at 1.8 and 2.3 kg, respectively. Their TSS values were high at 15.8 and 16.5 while their TA values were also high at 0.28 and 0.27%. Their TSS:TA ratio were 63 and 62, which were not significantly different from most of the other cultivars besides Hosui (the Asian pear) and Forelle, which had significantly higher TSS:TA ratios at 87 and 86, respectively. The DMC for both these genotypes was 0.19, which did not differ significantly from that for ‘Hosui’, ‘Forelle’, ‘Abate Fetel’ or ‘3D-37-38’, but it was higher and significantly different from the DMC for ‘P04-21’, ‘Packham’s Triumph’, ‘Red D’Anjou’ and ‘Cheeky’.

The pear flavour of Comice and Bon Chretien was double that of the lowest scoring cultivars, 3D-37-38 and Red D’Anjou, sweetness was also much higher, sour taste was lower, juiciness was higher and melt character was more than double (Table 6). The preferred fruit were soft, i.e. they scored very low for sensory hardness, but so did ‘3D-37-38’ one of the least favourite ones. Astringency was much higher in the lowest scoring fruit.

The sensory attribute of mealiness is a term describing fruit flesh developing a coarse, floury, soft and dry texture (Barreiro *et al*., 1998) and characterised by low extractable juice content. Previous studies (Cronje, 2014) found mealiness to be a negative driver for consumer preference and it is also the main internal quality disorder associated with the sensory quality of ‘Forelle’ pears in South Africa (Martin, 2002). Unfortunately, no mealiness was present in any of the samples used for this trial and it was therefore not possible to evaluate this attribute’s effect on consumer preference.

According to Harker *et al.* (2002), the validity of any instrumental measurement of texture should be based on how well it predicts the sensory profile. In a comparable consumer preference study on pears, Cronje (2014) found that sensory hardness correlated significantly with flesh firmness as measured with a penetrometer (r=0.88), and Van der Merwe (2013) found this to be true for apples as well. ‘Packham’s Triumph’, ‘Forelle’, ‘Abate Fetel’, ‘Red D’Anjou’ and ‘Hosui’ all scored above 3.3 kg for firmness. As it was not possible to have all cultivars at an equal level of ripeness, these cultivars might have scored higher for eating quality liking if they were riper, with the exception perhaps of ‘Hosui’ as this Asian pear is eating ripe straight off the tree and is consumed as a firm fruit. To the South African market, however, this is still a novel and unfamiliar pear and not widely consumed. In the marketing of the Asian pears in South Africa, it might be prudent to call it, and similar Asian pears and hybrids, by another name altogether so as to negate the idea that it will taste like a European pear and therefore leading to dissatisfied consumers.

The results indicate that the majority of consumers of all three ethnic groups, genders and ages in the Western Cape, show a preference for pears with a distinct pear flavour, a sweet taste but also containing a fair amount of acid, soft, juicy flesh with melt character, and a yellow or pale green peel colour with a typical pear shape (elongate-concave). This supports previous research by Manning (2009) on consumer preference of pears in the Western Cape, South Africa. It is important to note though that our assessment of appearance incorporated both colour and shape. A different experimental design would be needed to assess consumer preference of pear shape and colour separately. There were no large differences in preference for the three ethnic groups and this is similar to the results from a previous pear study by Jaeger *et al.* (2003) where there was no segmentation between New Zealand natives and recent immigrants from Taiwan who had lived in NZ less than one year. It differs though from the results of Van der Merwe (2013) who sourced consumers in the same area and found that black and coloured consumers generally preferred sweeter apples than white consumers. As pears are lower in acidity than apples, it could explain why there are no clear ethnic differences for preference of pear eating quality. In terms of drivers of liking, similar research done by Elkins *et al.* (2008) in the United States, found that sweetness and melting texture were the main reasons for consumers liking a European pear cultivar, while appearance, i.e., peel colour, was the least important factor. They also found that a gritty texture and lack of flavour were key reasons for disliking a cultivar. In this study and in the research done by Manning (2009), astringency was found to have a negative effect on consumer preference. Jaeger *et al.* (2003) found that consumers in New Zealand preferred European over Asian or hybrid genotype pears and, further, indicated a preference for ripe over unripe samples. The latter finding agreed with questionnaire responses from consumers describing their “ideal” pears as sweet and juicy. These two attributes were the distinguishing differences between ripe and unripe samples and correlates well with our findings.

Our results superficially suggest that South Africans do not necessarily prefer the appearance of blushed pears. However, we did not present consumers with photos of blushed pears with a typical pear shape. Steyn *et al*. (2011) found that South African consumers gave the highest preference score for bright coloured pears like Rosemarie, a pink-blushed cultivar with a typical pyriform shape, but did not like red pears. Since maturity is the main factor that determines the eating quality of European pears and maturity changes are easier to see on blushed and non-blushed cultivars, it is more difficult to assess the maturity of a full red pear. Consequently, the consumer may more often end up with a negative eating experience with red pears and this could be why red pears are not liked so much (Steyn, 2011). This could also explain why P04-21 in our study did not score high for appearance even though it scored the same as 'Forelle' for eating quality. Appearance scores for Forelle, a bi-colour cultivar, showed a clear difference between ethnic groups, scoring significantly higher with the white consumers. This might be due to greater exposure of white consumers to this cultivar, which is usually marketed at higher prices at more upmarket retail outlets.

The two consumer clusters identified showed no obvious differences in composition in terms of gender, ethnicity or age. Both clusters preferred the eating quality of 'Comice' and 'Bon Chretien' overall, while a clear difference in their preference is indicated by their scoring of 'Hosui', the Asian pear, in particular. Specifically, group 1 scored 'Abate Fetel', 'Forelle', 'Packham's Triumph' and 'Hosui' similarly, approximately 6 on the hedonic scale, illustrating a moderate liking of the overall eating quality of the pears. This group of consumers scored 'P04-21' and 'Red D'Anjou' slightly lower than the latter four pears, probably because the inherent quality of the overall pear flavour and texture was lower. As mentioned, group 2 scored 'Comice' and 'Bon Chretien' very high for preference of eating quality. Similarly, 'Cheeky' was also scored high for preference of eating quality. This indicates that this group of consumers used the upper part of the hedonic scale when they liked a product irrespective of whether the cultivar was familiar or not to the general pear-eating consumer. Group 2 scored 'Forelle' quite low but preferred it to Hosui that they scored even lower. This could indicate that, although not everyone liked 'Hosui', there was a substantial number of local consumers i.e. group 1 (55%) who would potentially buy Asian pears marketed in South Africa.

With regard to the appearance of pears, group 1 all equally liked 'Bon Chretien', 'Cheeky', 'Forelle', 'P04-21', 'Packham's Triumph' and 'Red D'Anjou'. This group seemed to like different pear shapes and colours, therefore their preference for pear appearance varied. Group 2 preferred the appearance of 'Bon Chretien' and 'Packham's Triumph' significantly more than any other pears. These are the main cultivars grown in South Africa (HORTGRO, 2014) and have been on the market the longest. It could be that this familiarity with the products is why group 2 preferred their appearance.

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Conclusions

This study clearly indicated two groups of pear consumers. Group 2 had a small selection of cultivars that they really liked for appearance and eating quality. Interestingly they used the upper part of the hedonic scale (hedonic score >7) for the small selection of cultivars that they really liked. In contrast, group 1 indicated a liking for a wider range of cultivars, but they used the lower part of the hedonic scale and their like and dislikes were not as clearly defined. This makes it difficult to market pears in South Africa with its very diverse consumer base.

It has previously been suggested that the difficulty pears face in the marketplace relates predominantly to ripeness (Bruhn *et al*. 1991). Kappel *et al.* (1995) and Echer Zerbini (2002) found that the right texture, high juiciness, taste (sweetness) and aroma (typical of each cultivar) are important attributes associated with eating quality of pears. As these attributes change during ripening, the eating quality of pears relates to their maturity. The rapid progression of pears from unripe to overripe makes it difficult for consumers to accurately assess their eating quality and is one of the reasons why consumers do not buy pears (Raffo *et al*., 2011). According to Elkins and Mitcham (2007), consumers preferred ripened pears by a margin of 3 to 1 over unripe pears and suggested that pears should be ripened at or near the retail market as partially ripe fruit are much more susceptible to bruising injury during transportation. Storage personnel should also be trained to handle partially ripened fruit carefully. This study agrees with these previous findings. Producers and retailers would like consumers to repeatedly buy unripe pears as it is convenient to transport and minimises losses on their side. While there is a market segment that preferred harder pears, most consumers still preferred soft, sweet, juicy pears.

What is interesting to note is that the 'Bon Chretien' used for this trial was allowed to ripen on the tree and was then kept in cold storage for 3 months. This suggests that allowing pears to ripen on the tree could make a huge difference in consumer satisfaction and subsequently lead to increased sales.

Further research on this subject could include using the same cultivar at various stages of ripeness and also assess how harvest times may influence consumer preference. The research should be repeated for a number of consecutive seasons as the level of mealiness may differ between seasons even when fruit is harvested at the same maturities.

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Table 1 Terminology for descriptive sensory analysis (Source: Daillant-Spinnler *et al.*, 1996).

Attributes	Description	Scale
Overall pear flavour	Aromatics of typical pear	0= None ; 100=Very strong pear flavour
Sweet taste	Basic taste caused by characteristic sugars, e.g. sucrose	0= None ; 100=Prominent sweet taste
Sour taste	Basic taste caused by characteristic acids, e.g. citric acid	0= None ; 100=Prominent sour taste
Astringency	The sensation associated with drying of the mouth	0=None ; 100=Prominent dry mouthfeel
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 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 (first three chews)	0= None ; 100=Very juicy
Mealiness	Degree to which the flesh breaks down to very fine dry particles	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 2 Physicochemical measurements including firmness (kg), total soluble solids (TSS, ˚Brix), titratable acidity (TA, % malic acid), TSS:TA ratio and dry matter concentration (DMC) for pear cultivars harvested at Simondium and Ceres, South Africa in 2012.

	P 04-21	**Packham's Triumph**	**Comice**	**Bon Chretien**	**Hosui**	**Red D' Anjou**	**Forelle**	**Cheeky**	**Abate Fetel**	***3D-37-38***	***p-value***^{z}
Firmness (kg)	2.8 ^{cdz}	3.5 ^{abc}	1.8 ^{e}	2.3 ^{de}	3.5 ^{abc}	3.6 ^{ab}	3.9 ^{a}	3.0 ^{bcd}	3.3 ^{abc}	2.9 ^{bcd}	*0.0010*
TSS (˚Brix)	9.3 ^{dz}	13.2 ^{bc}	15.8 ^{a}	16.5 ^{a}	15.6 ^{a}	10.4 ^{d}	16.6 ^{a}	12.8 ^{c}	14.0 ^{b}	*14.3* ^{b}	*0.0140*
TA (% malic acid)	0.15 ^{ez}	0.23 ^{abc}	0.28 ^{a}	0.27 ^{ab}	0.18 ^{cde}	0.21 ^{bd}	0.20 ^{cde}	0.17 ^{de}	0.20 ^{cde}	0.28 ^{a}	*0.0010*
TSS:TA ratio	61.71 ^{bcz}	59.20 ^{bc}	63.56 ^{bc}	62.40 ^{bc}	86.84 ^{a}	49.24 ^{c}	86.01 ^{a}	75.20 ^{ab}	70.68 ^{ab}	52.33 ^{c}	*0.0100*
DMC (%)	0.12 ^{dz}	0.16 ^{bc}	0.19 ^{a}	0.19 ^{a}	0.17 ^{ab}	0.13 ^{cd}	0.19 ^{a}	0.16 ^{bc}	0.20 ^{a}	0.18 ^{ab}	*0.0037*

^{Z} Means with different letters differ significantly at P≤0.05 in the row

Table 3 The sensory characteristics of ten pear cultivars harvested at LNR pear breeding facility, Simondium and Ceres, South Africa between February and April 2012. Measurements were done on a 100-mm unstructured line scale ranging from 0 to 100 according to the perceived strength of the attributes during descriptive sensory analysis in 2012.

	P 04-21	Packham's Triumph	Comice	Bon Chretien	Hosui	Red D' Anjou	Forelle	Cheeky	Abate Fetel	3D-37-38	*p-value*[Z]
Pear flavour	36 [e]	37 [e]	66 [ab]	75 [a]	40 [de]	38 [de]	48 [cd]	56 [bc]	59 [bc]	32 [e]	*0.0001*
Sweet taste	31 [d]	36 [d]	58 [ab]	63 [a]	48 [c]	38 [d]	46 [c]	47 [c]	54 [bc]	32 [d]	*0.0001*
Sour taste	11 [c]	20 [a]	12 [c]	15 [b]	11 [c]	13 [bc]	15 [b]	12 [c]	12 [c]	19 [a]	*0.0001*
Astringency with peel	7 [c]	18 [b]	6 [c]	4 [c]	8 [c]	9 [c]	3 [c]	9 [c]	5 [c]	44 [a]	*0.0001*
Hardness	34 [bcd]	44 [a]	20 [f]	26 [ef]	38 [abc]	40 [ab]	42 [a]	32 [cde]	41 [ab]	28 [de]	*0.0001*
Melt character	24 [be]	14 [e]	60 [a]	52 [a]	32 [bc]	22 [ec]	18 [de]	33 [b]	28 [bcd]	26 [bcd]	*0.0001*
Juiciness	52 [bd]	45 [ef]	60 [a]	58 [ab]	59 [a]	47 [df]	45 [fe]	55 [abc]	51 [cde]	44 [f]	*0.0001*
Grittiness	36 [ab]	33 [bc]	33 [bc]	28 [c]	37 [ab]	33 [bc]	33 [bc]	36 [ab]	35 [b]	41 [a]	*0.0050*

[Z] Means with different letters differ significantly at $P \le 0.05$ in the row

Table 4 Consumer liking of ten pear cultivars with regard to eating quality and appearance. A nine-point hedonic scale was used where 9=*'Like extremely'* and 1=*'Dislike extremely'*. Pears were harvested at ARC pear breeding facility, Simondium and Dwarsberg farm, Ceres, Western Cape, South Africa between February and April 2012. Pears were stored at -0.5℃ and ripened at room temperature 7 days before testing.

Cultivar	Liking of Eating quality	Liking of Appearance
3D-37-38	4.0 [f]	6.4 [b]
Abate Fetel	6.0 [c]	6.1 [bc]
Bon Chretien	7.0 [a]	7.3 [a]
Cheeky	6.7 [b]	6.1 [bc]
Comice	7.3 [a]	5.3 [d]
Forelle	5.7 [c]	5.9 [c]
Hosui	5.3 [d]	4.8 [e]
P04-21	4.5 [e]	6.1 [bc]
Packham's Triumph	6.0 [c]	7.2 [a]
Red D'Anjou	4.3 [e]	5.5 [d]
p-value [z]	*0.0001*	*0.0001*

[Z] Means with different letters differ significantly at P≤0.05 in the column

Table 5. Pearson's correlation matrix for consumer preference of eating quality for ten pear cultivars with sensory attributes analysed by the trained panel and instrumental measurements included fruit firmness (kg), total soluble solids (TSS), titratable acidity (TA), TSS:TA and dry matter content (DMC %). Sensory attributes included pear flavour, sweet taste, sour taste, astringency with peel, hardness, melt character, juiciness and grittiness. Values in bold correlated significantly (P≤0.05).

TSS (°Brix)	TA (%malix acid)	TSS:TA	DMC (%)	Firmness (kg)	Pear flavour	Sweet taste	Sour taste	Astrin-gency	Hardness	Melt character	Juiciness	Grittiness	Liking of Eating quality
1	0.523	0.499	**0.895**	-0.162	0.535	**0.684**	0.186	-0.069	-0.261	0.451	0.284	-0.251	0.551
0.523	**1**	-0.465	0.538	-0.528	0.330	0.315	0.552	0.430	-0.574	0.503	-0.001	-0.199	0.247
0.499	-0.465	**1**	0.371	0.318	0.192	0.363	-0.397	-0.482	0.252	-0.009	0.323	0.014	0.328
0.895	0.538	0.371	**1**	-0.196	0.597	**0.692**	0.179	-0.006	-0.233	0.415	0.178	-0.152	0.550
-0.162	-0.528	0.318	-0.196	**1**	-0.583	-0.440	0.161	0.000	**0.933**	**-0.875**	-0.626	0.193	-0.484
0.535	0.330	0.192	0.597	-0.583	**1**	**0.940**	-0.290	-0.546	-0.497	**0.787**	**0.641**	**-0.660**	**0.867**
0.684	0.315	0.363	**0.692**	-0.440	**0.940**	**1**	-0.339	-0.571	-0.388	**0.766**	**0.698**	-0.608	**0.827**
0.186	0.552	-0.397	0.179	0.161	-0.290	-0.339	**1**	**0.678**	0.130	-0.349	**-0.661**	0.040	-0.150
-0.069	0.430	-0.482	-0.006	0.000	-0.546	-0.571	**0.678**	**1**	-0.149	-0.259	-0.513	**0.674**	-0.523
-0.261	-0.574	0.252	-0.233	**0.933**	-0.497	-0.388	0.130	-0.149	**1**	**-0.861**	-0.570	0.035	-0.360
0.451	0.503	-0.009	0.415	**-0.875**	**0.787**	**0.766**	-0.349	-0.259	**-0.861**	**1**	**0.825**	-0.359	**0.656**
0.284	-0.001	0.323	0.178	-0.626	**0.641**	**0.698**	**-0.661**	-0.513	-0.570	**0.825**	**1**	-0.279	0.609
-0.251	-0.199	0.014	-0.152	0.193	**-0.660**	-0.608	0.040	**0.674**	0.035	-0.359	-0.279	**1**	-0.607
0.551	0.247	0.328	0.550	-0.484	**0.867**	**0.827**	-0.150	-0.523	-0.360	**0.656**	0.609	-0.607	**1**

Table 6. Consumer liking and sensory attribute scores for pear characteristics of the two **highest** and the two **lowest** scoring cultivars. Cultivars' position out of 10 for each characteristic is given in brackets.

Cultivar	Liking	Flavour	Sweet	Sour	Juicy	Melting	Hard	Astringency
Comice	7.3	66 (2)	58 (2)	12 (7)	60 (1)	59 (1)	20 (10)	6.0 (7)
Bon Chretien	7.2	75 (1)	64 (1)	15 (3)	58 (3)	52 (2)	26 (9)	4.4 (9)
Red D'Anjou	4.2	38 (7)	38 (7)	15 (5)	47 (7)	22 (7)	40 (4)	9.3 (3)
3D-37-38	3.8	32 (10)	32 (10)	19 (2)	44 (10)	26 (5)	28 (8)	44.3 (1)

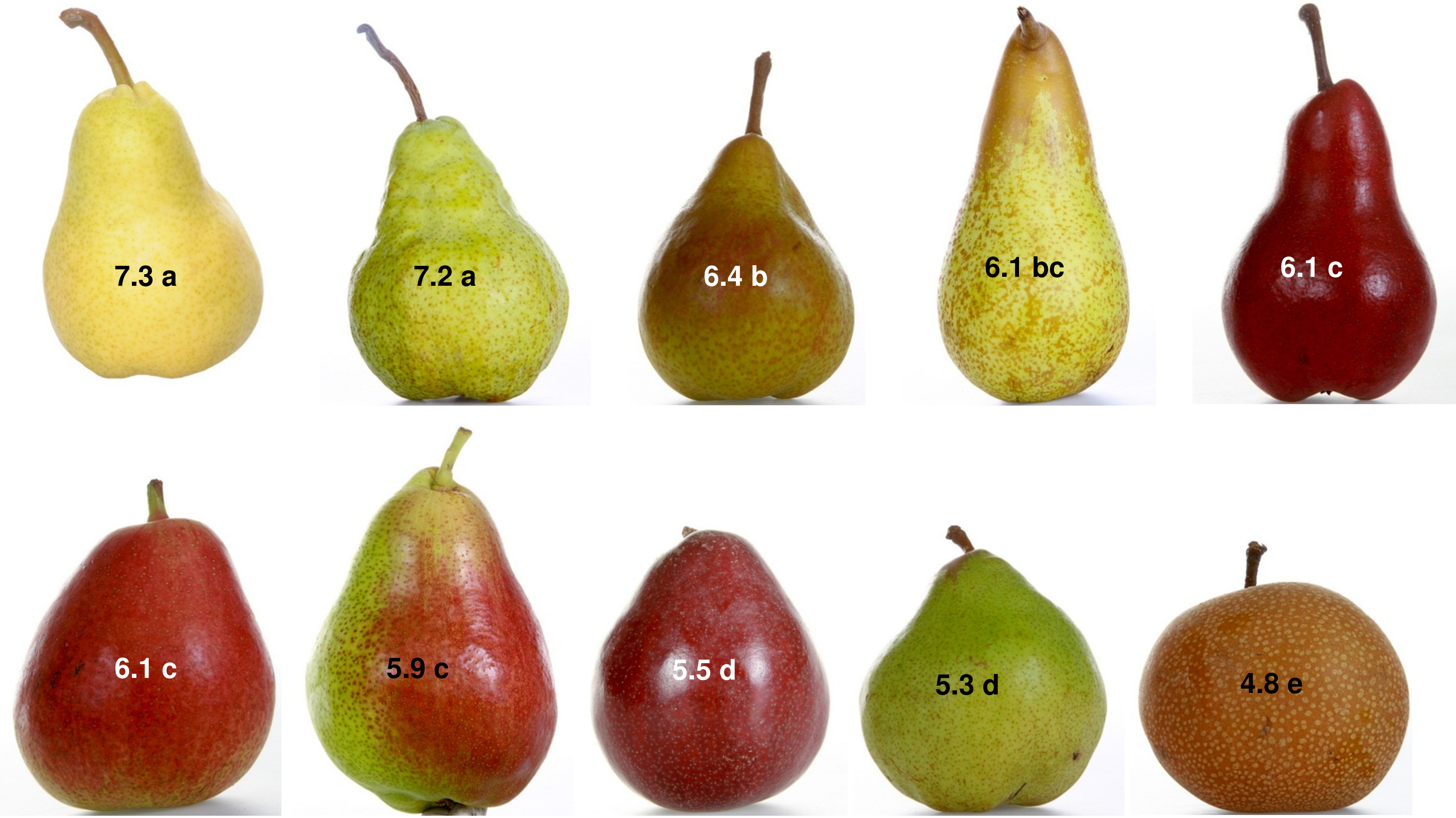

Figure 1. Mean scores with significant letters for consumer preference for appearance of ten pear cultivars, i.e. from the top left to right: ‘Bon Cretien’, ‘Packham’s Triumph’, 3D-37-38, ‘Abate Fetel’, P04-21, ‘Cheeky’, ‘Forelle’, ‘Red D’Anjou’, ‘Comice’ and ‘Hosui’.

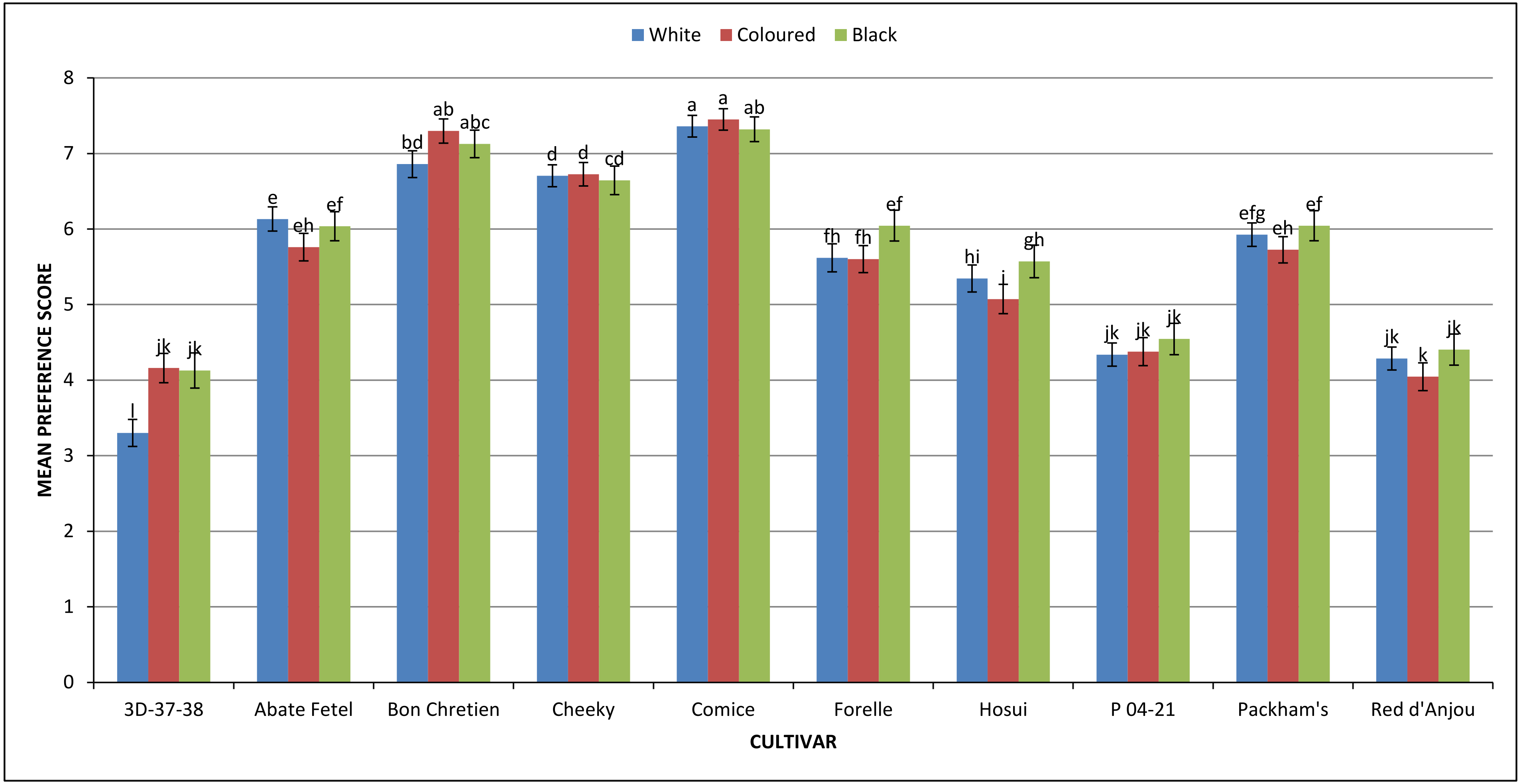

Figure 2. Mean preference scores for the eating quality of ten pear cultivars for three ethnic groups in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

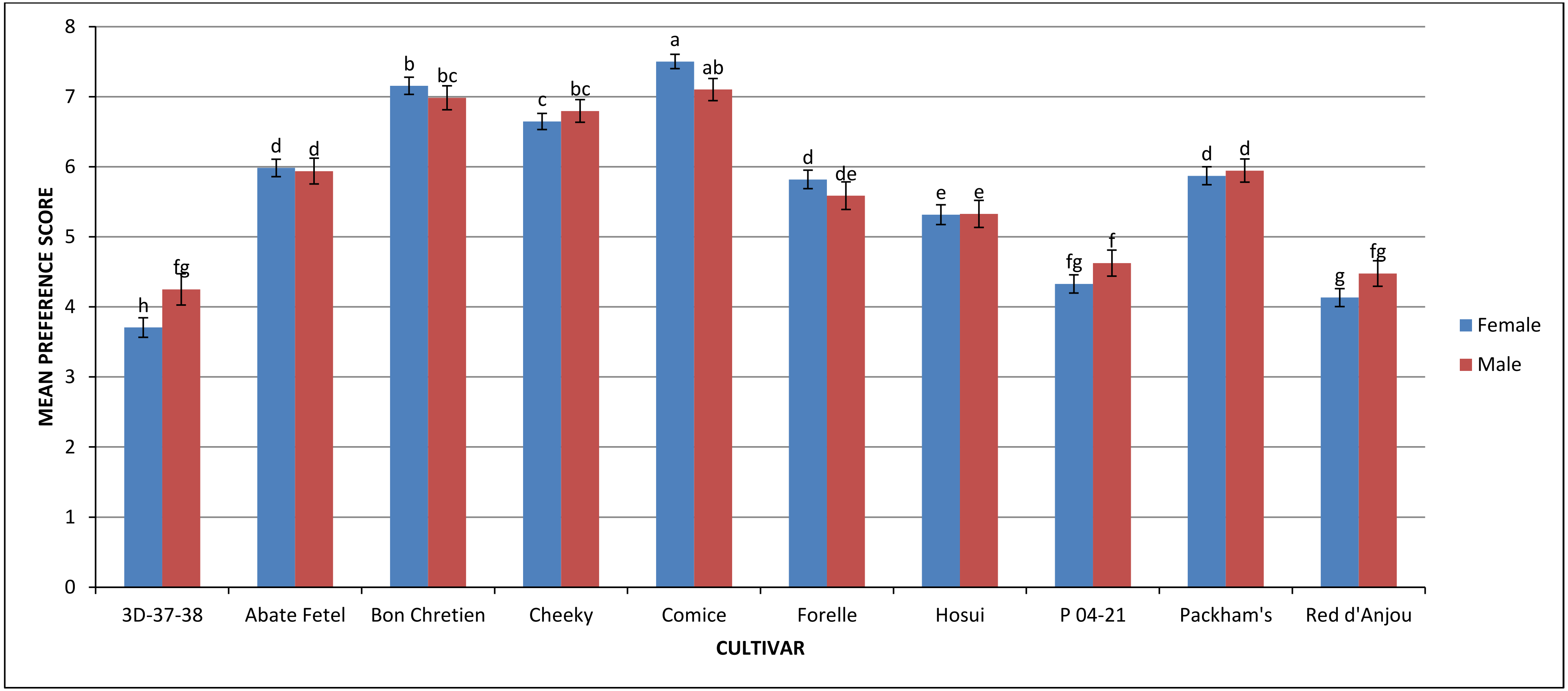

Figure 3. Mean preference scores for the eating quality of ten pear cultivars with regard to consumer gender in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

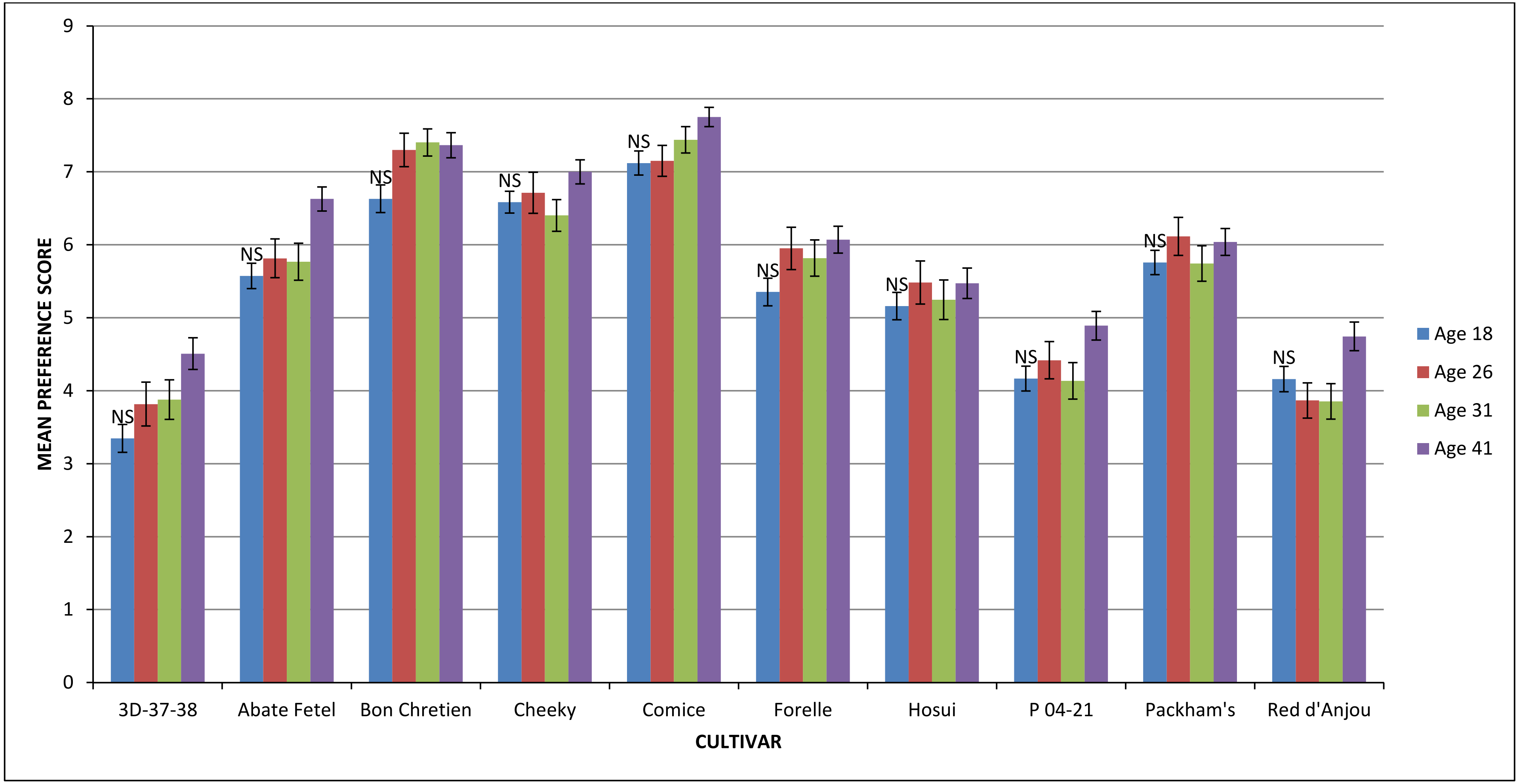

Figure 4. Mean preference scores for eating quality of ten pear cultivars for different age groups of consumers in the Western Cape, South Africa. ^{NS} Not significant

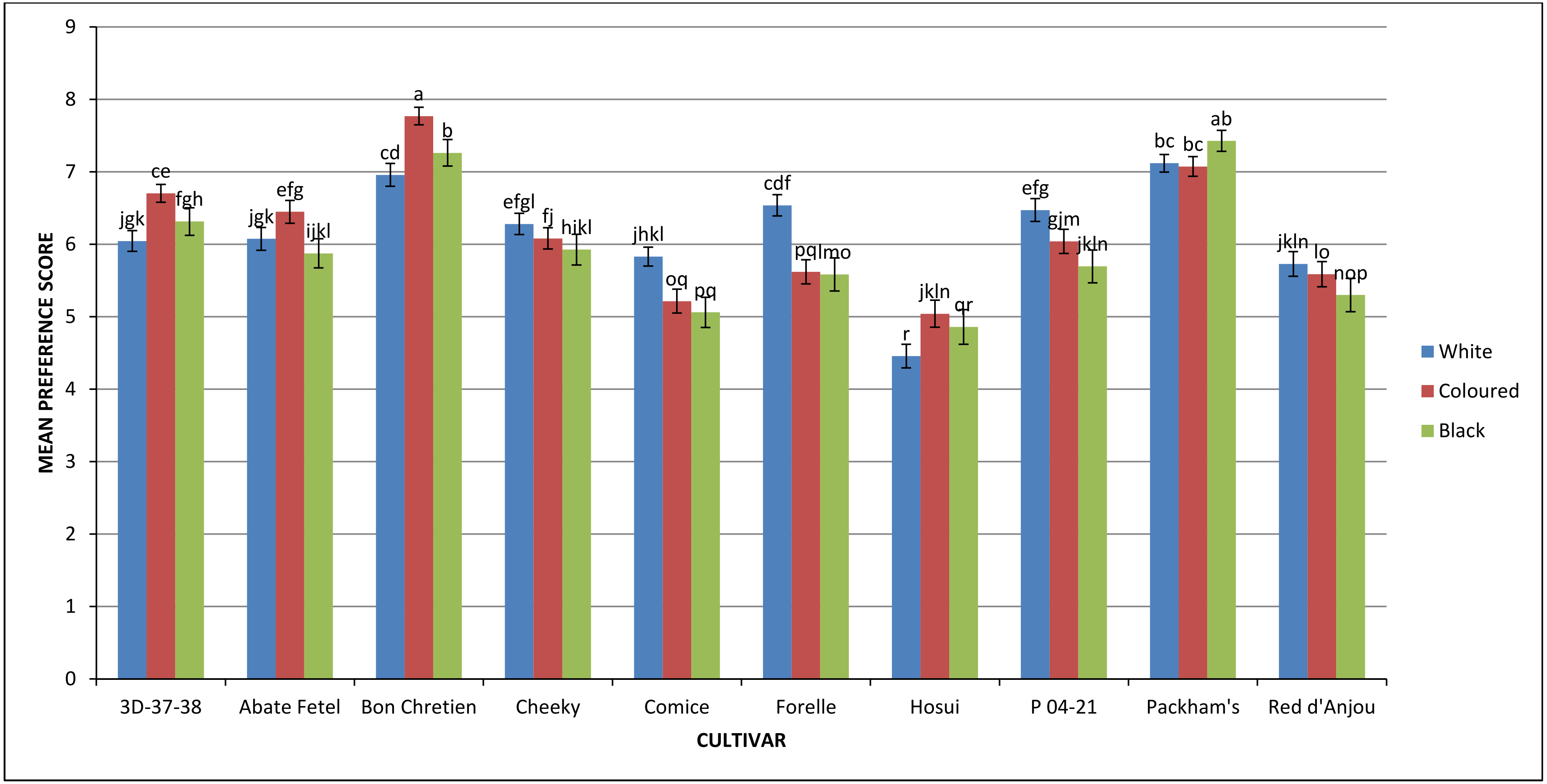

Figure 5. Mean preference scores for the appearance of ten pear cultivars for three ethnic groups in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

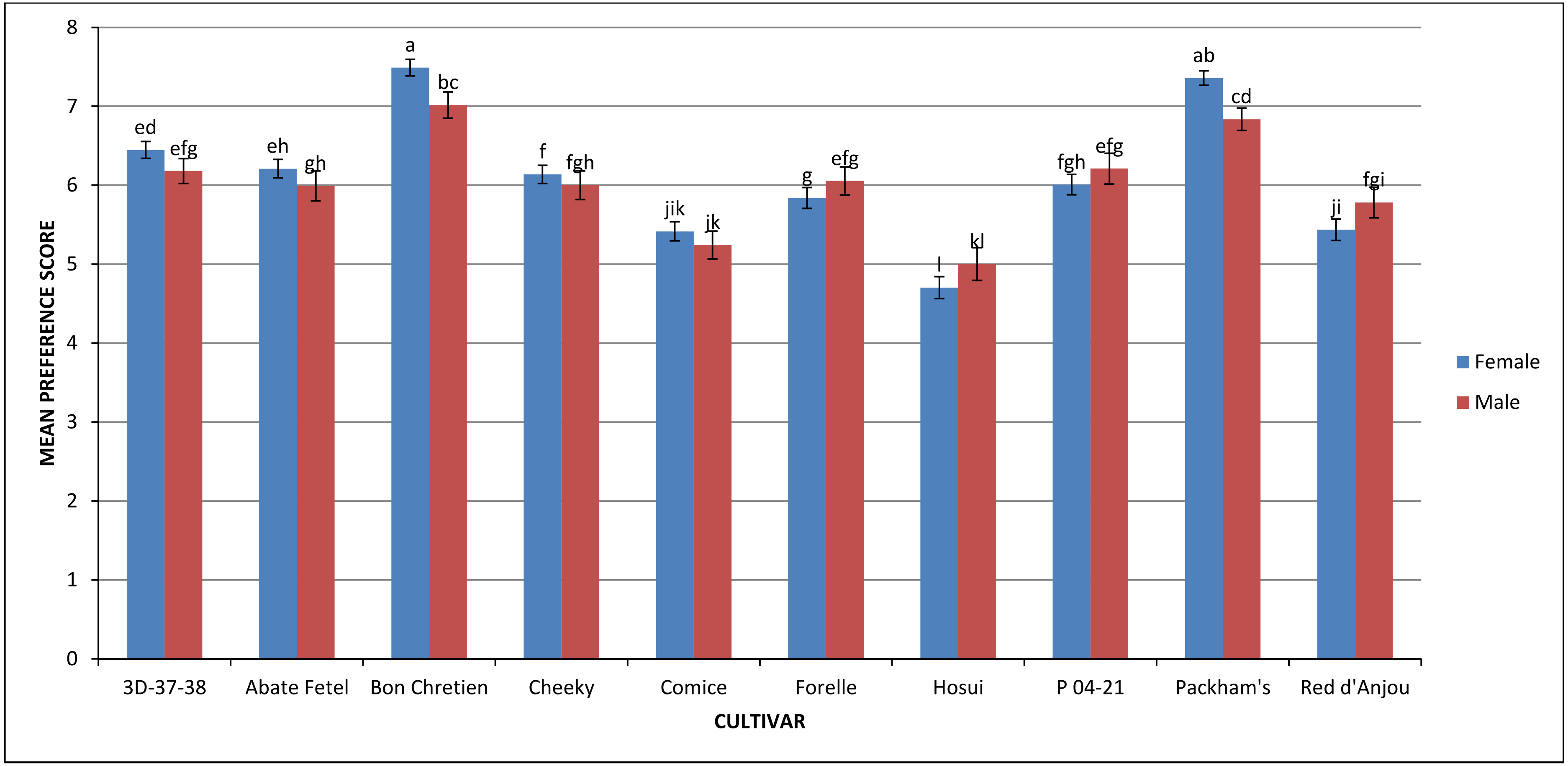

Figure 6. Mean preference for appearance of ten pear cultivars with regard to gender for consumers in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

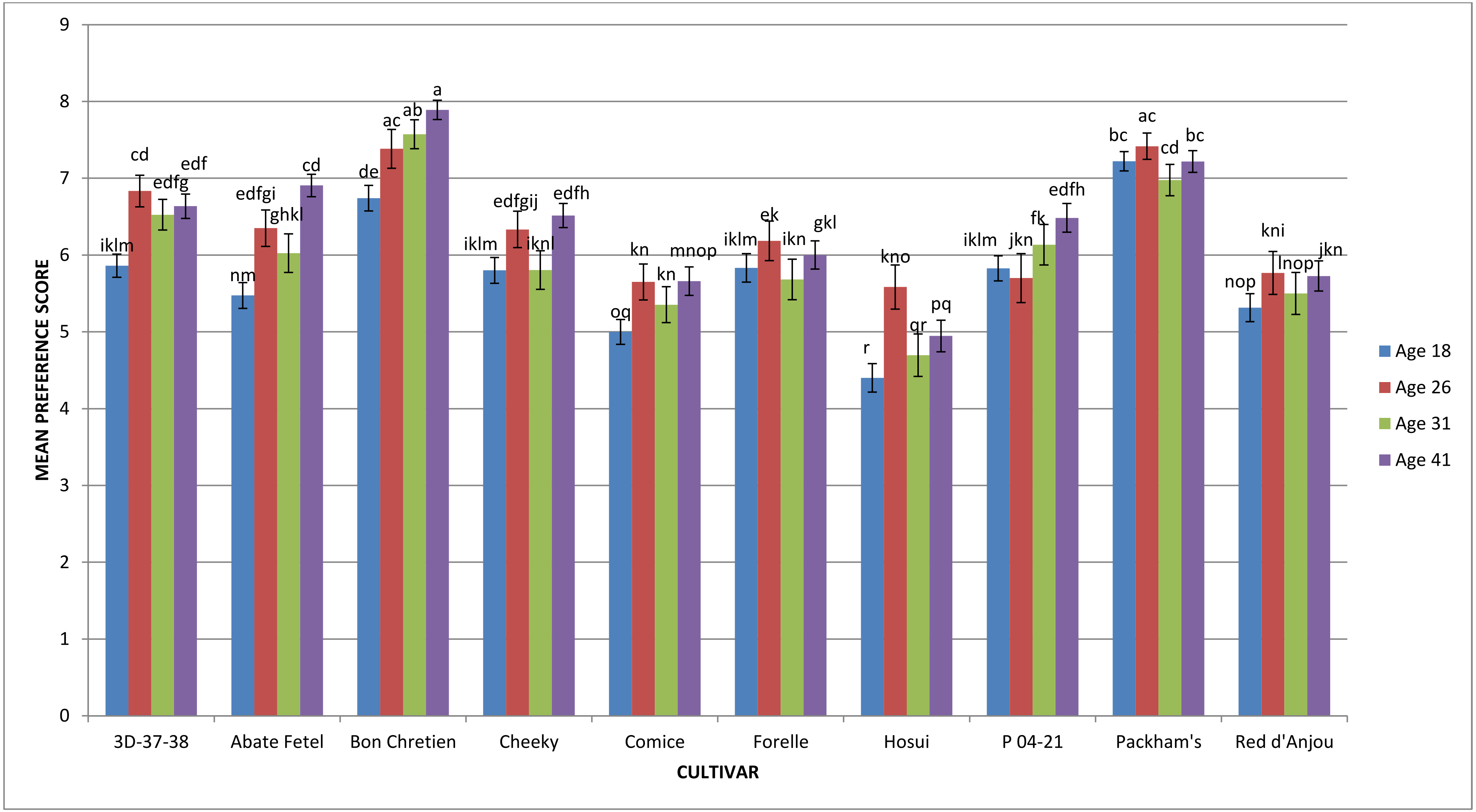

Figure 7. Mean preference for appearance of ten pear cultivars with regard to consumer age for consumers in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

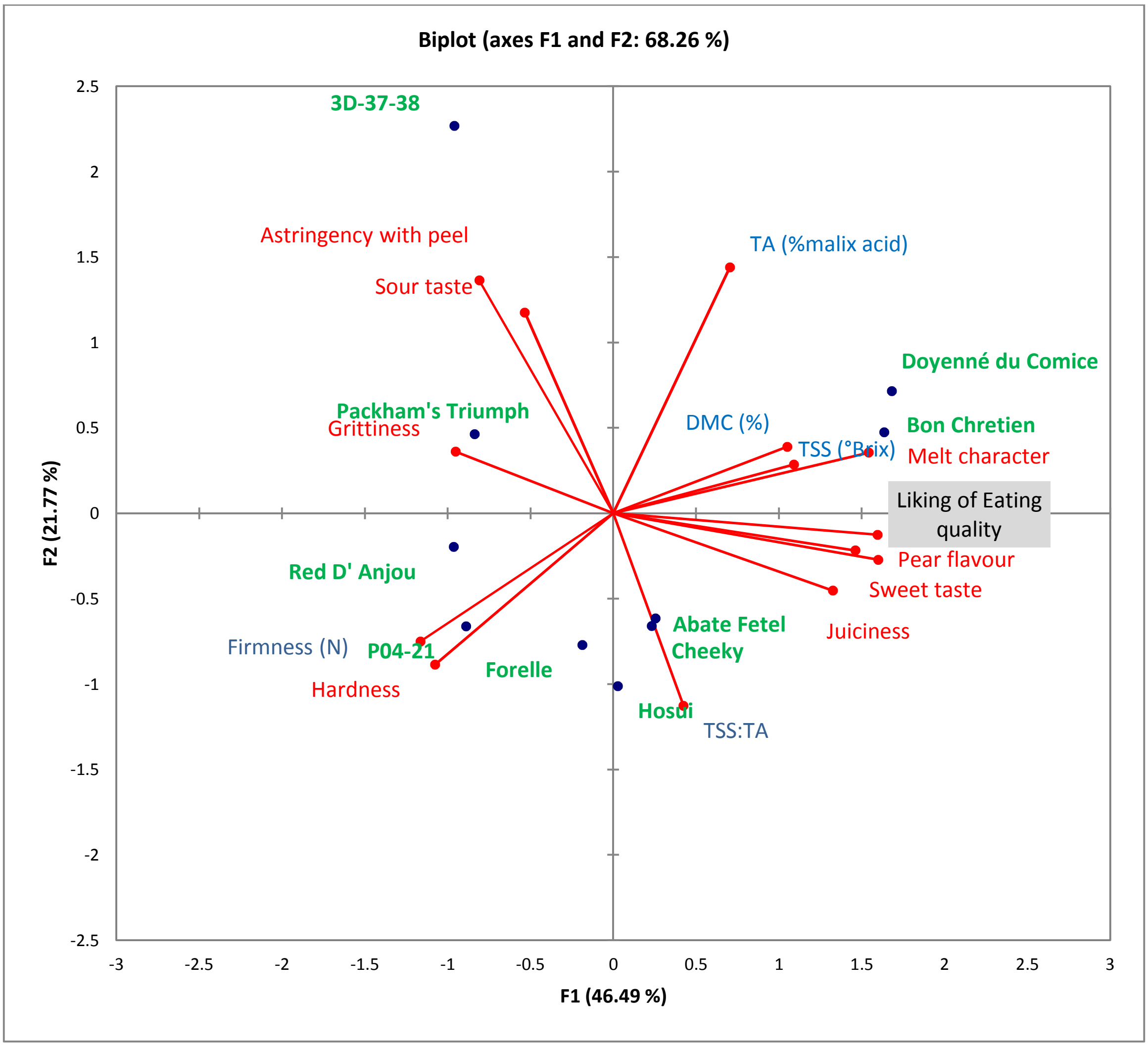

Figure 8. PCA bi-plot indicating association between the physiochemical measurements (in blue), sensory attributes (in red), cultivars (in green) and liking of eating quality (grey square).

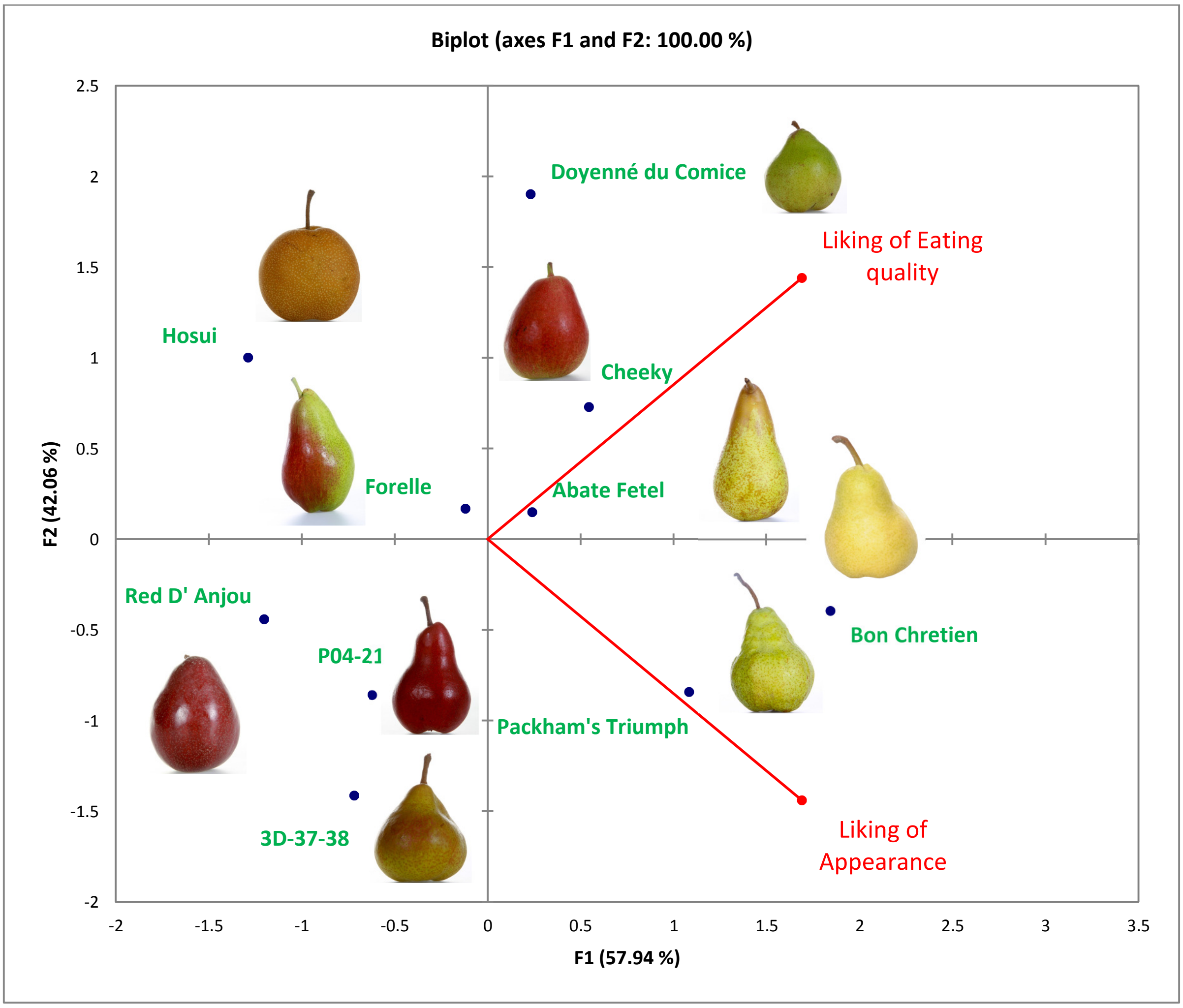

Figure 9. PCA bi-plot showing consumer liking for eating quality and appearance (in red) of ten pear cultivars (in green).

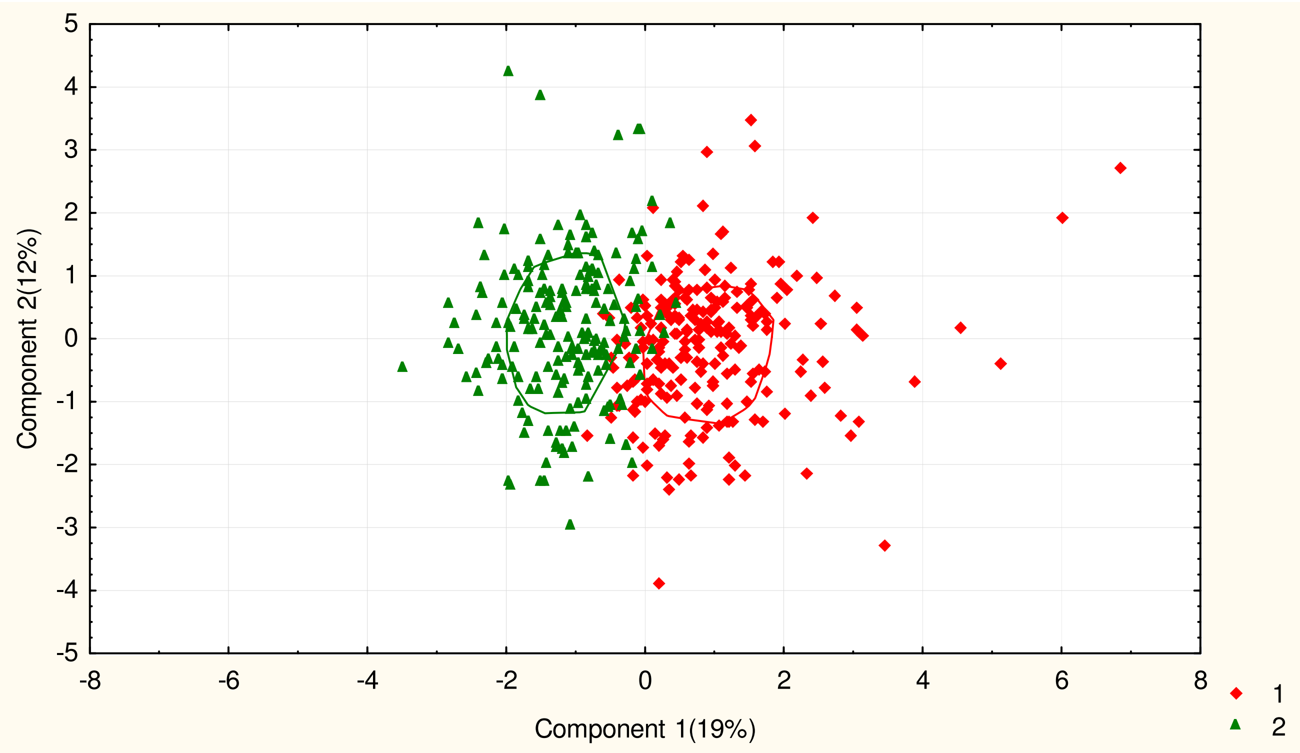

Figure 10. PCA plot showing only two consumer clusters for eating quality liking identified with the K-Means method on component 1.

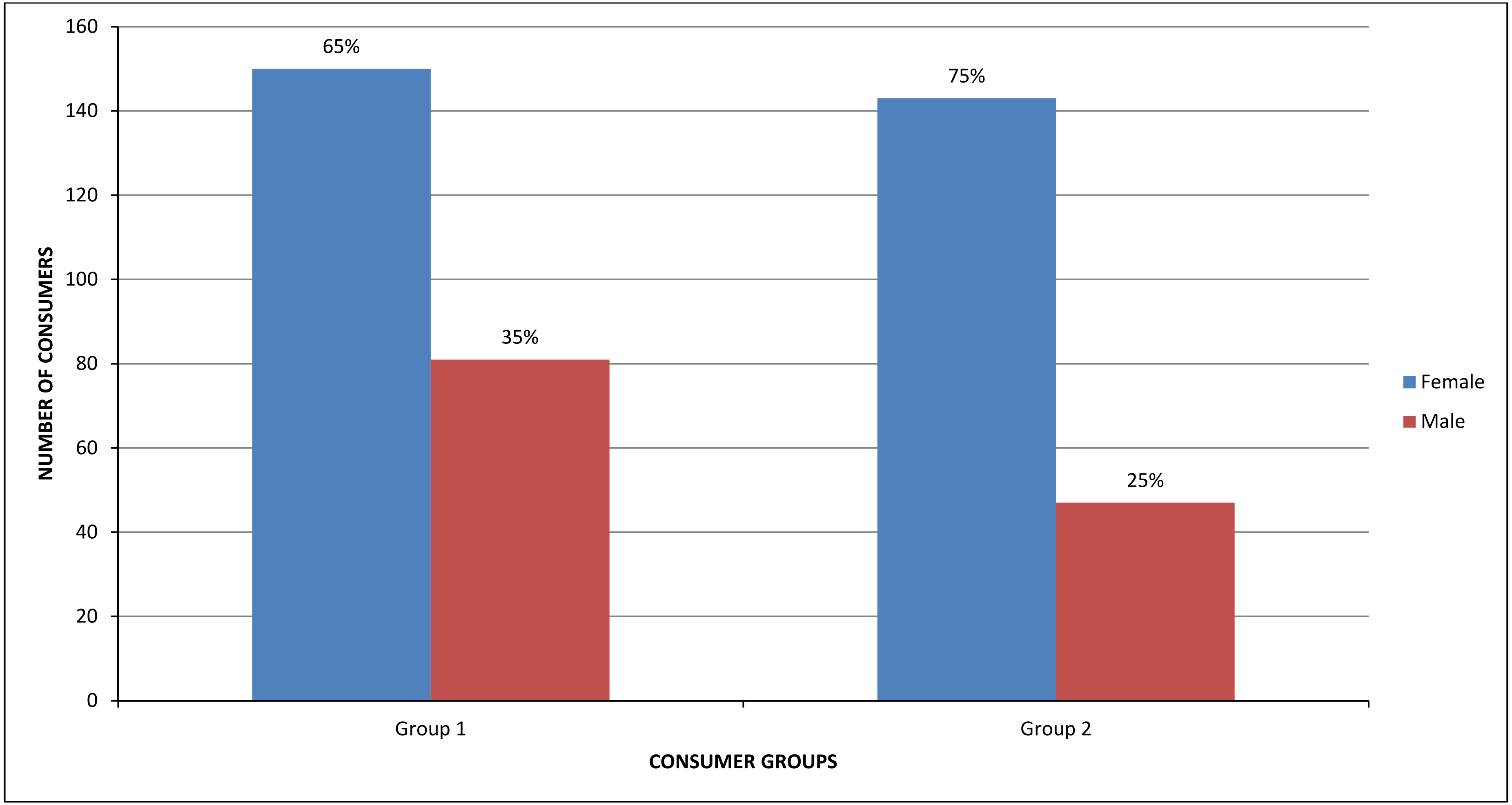

Figure 11. Histogram of the gender distribution (f = Female and m = Male) of consumer groups 1 and 2 with regard to pear eating quality.

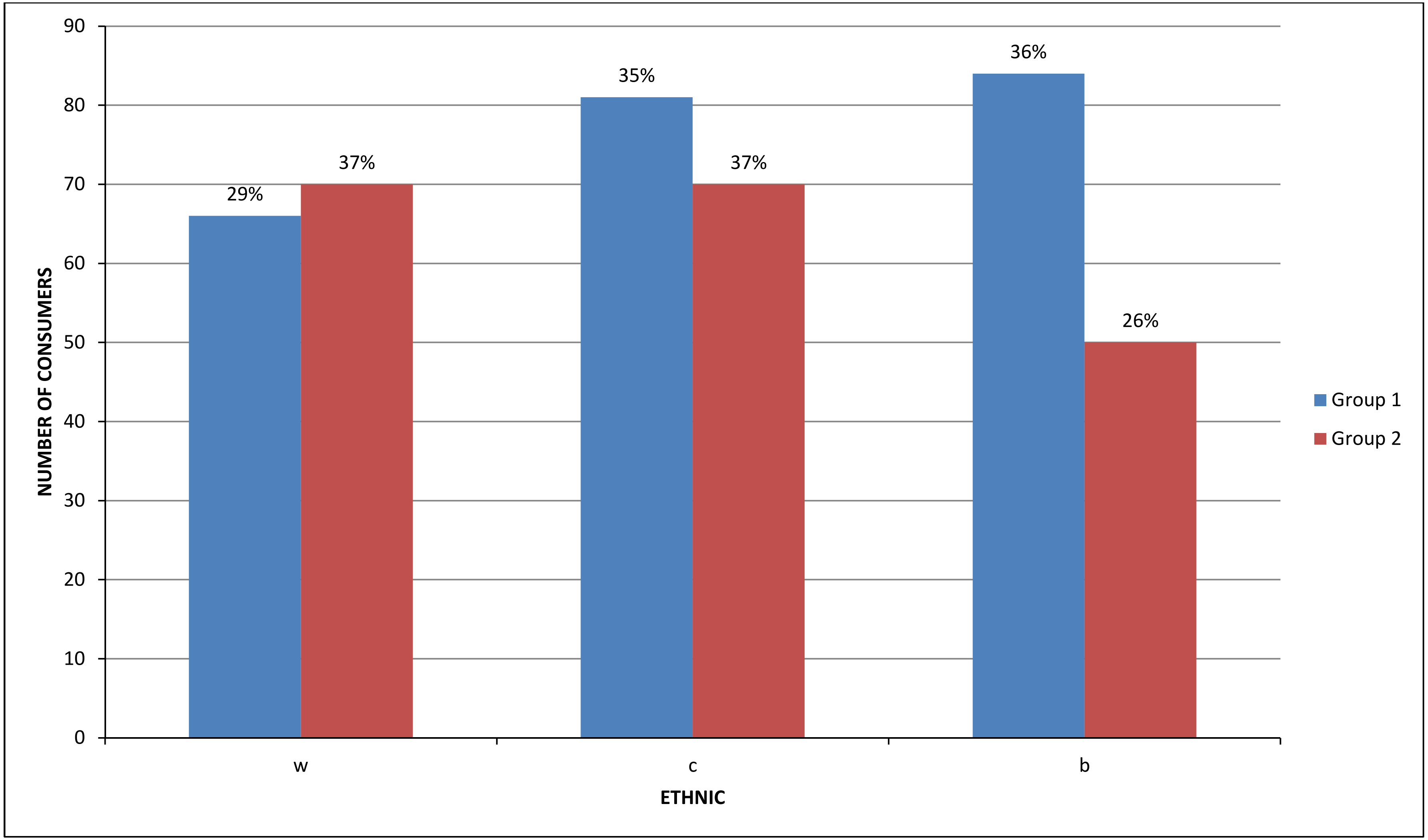

Figure 12. Histogram of ethnic distribution of consumers in groups 1 and 2 (w = White, c = Coloured and b = Black consumers) with regard to eating quality of pears.

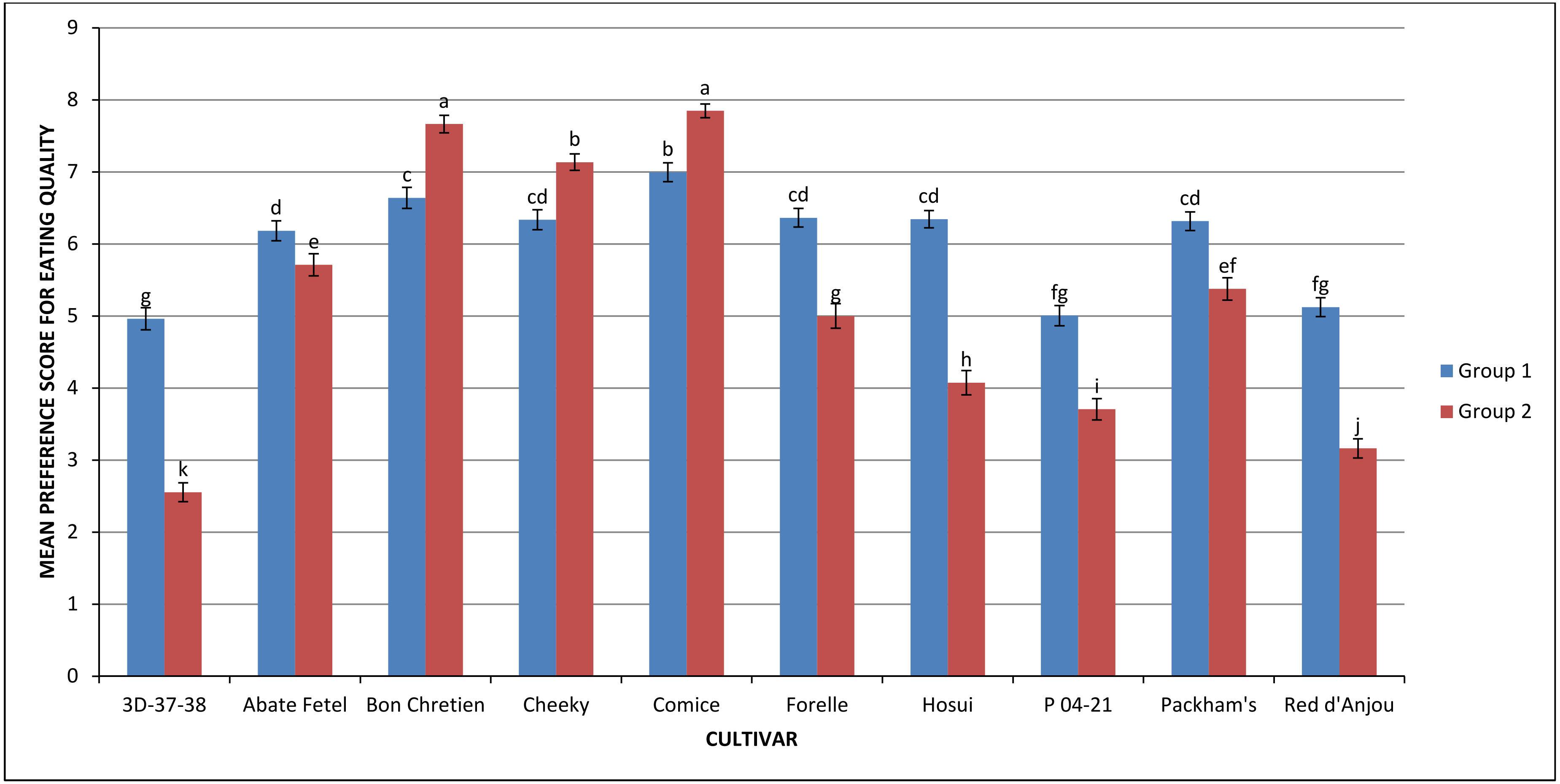

Figure 13. Mean preference scores for eating quality of ten pear cultivars for different consumer groups in the Western Cape, South Africa. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

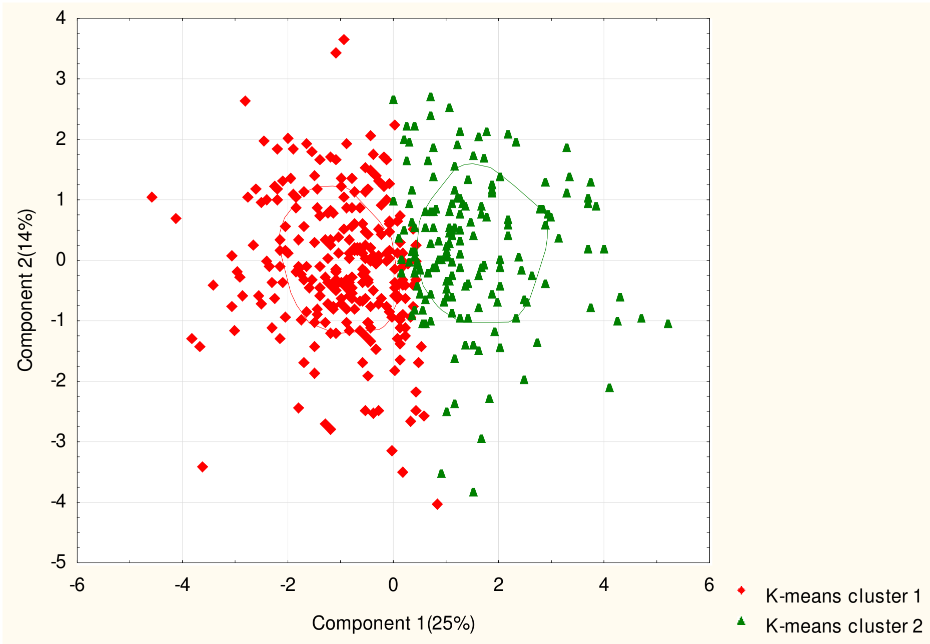

Figure 14. PCA plot showing the two consumer clusters for appearance liking identified with the K-Means method.

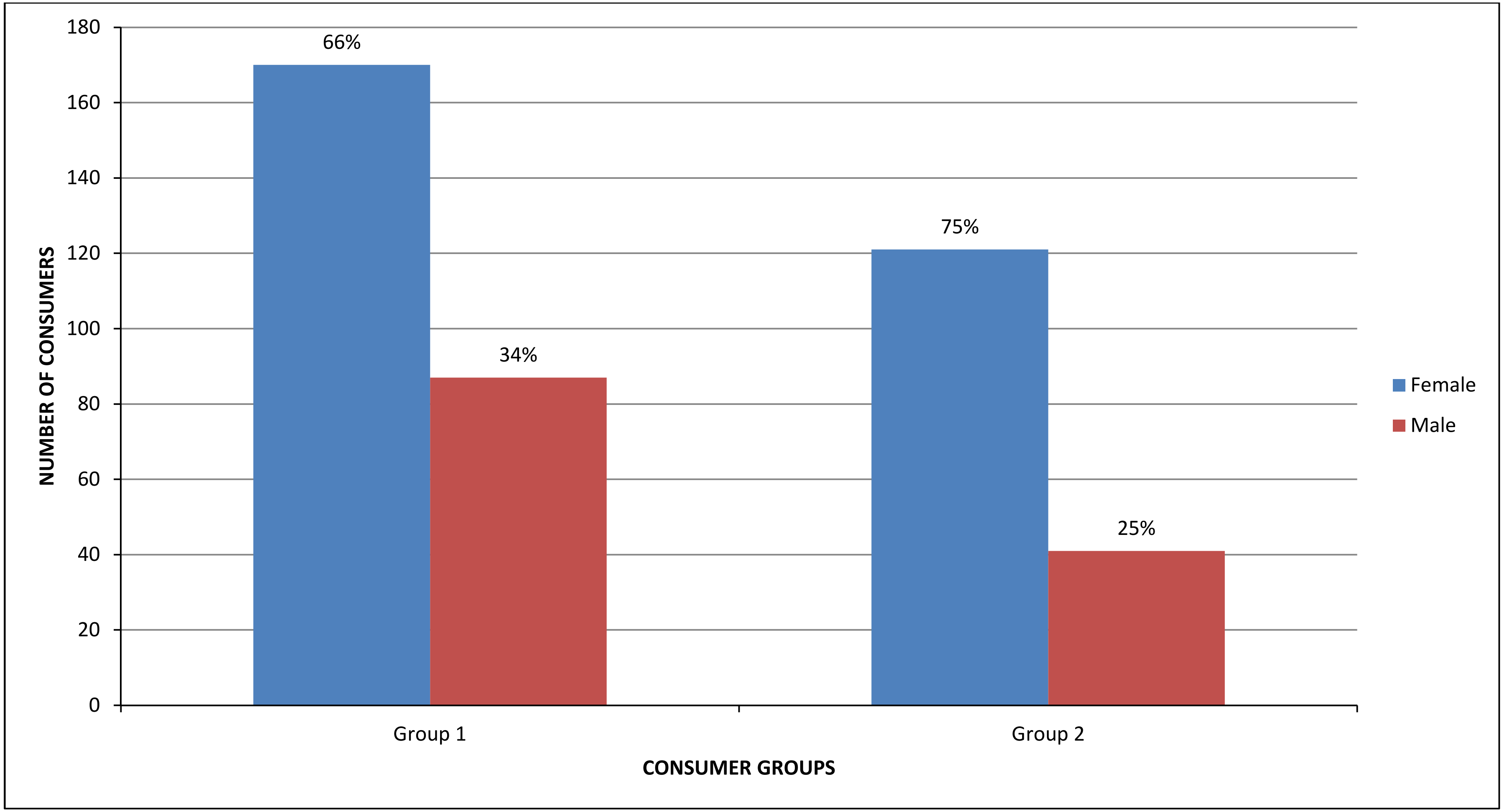

Figure 15. Histogram of the gender distribution of consumer groups 1 and 2 with regard to preference for pear appearance.

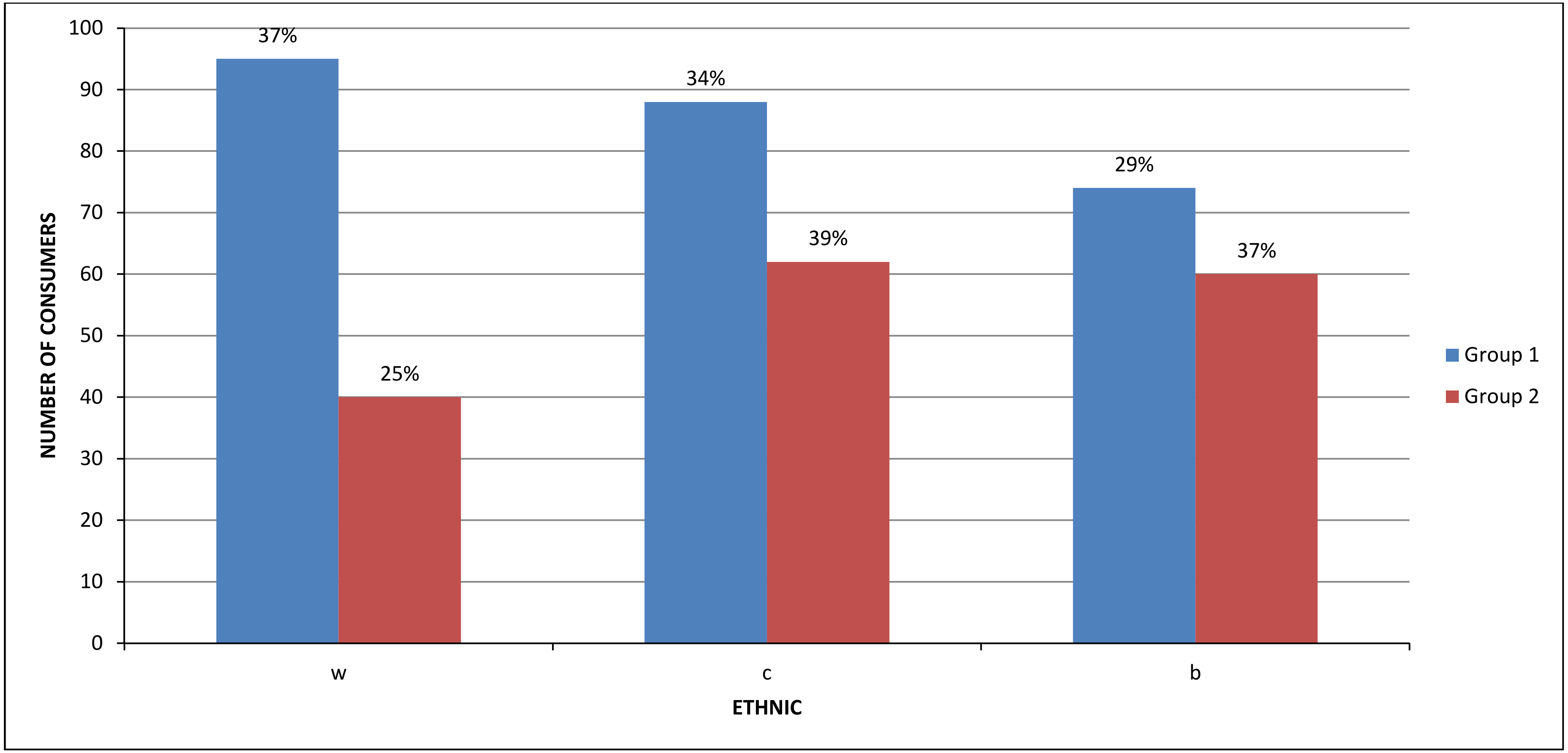

Figure 16. Histogram of the ethnic distribution of consumer groups 1 and 2 (w = White, c = Coloured and b = Black consumers) with regard to pear appearance.

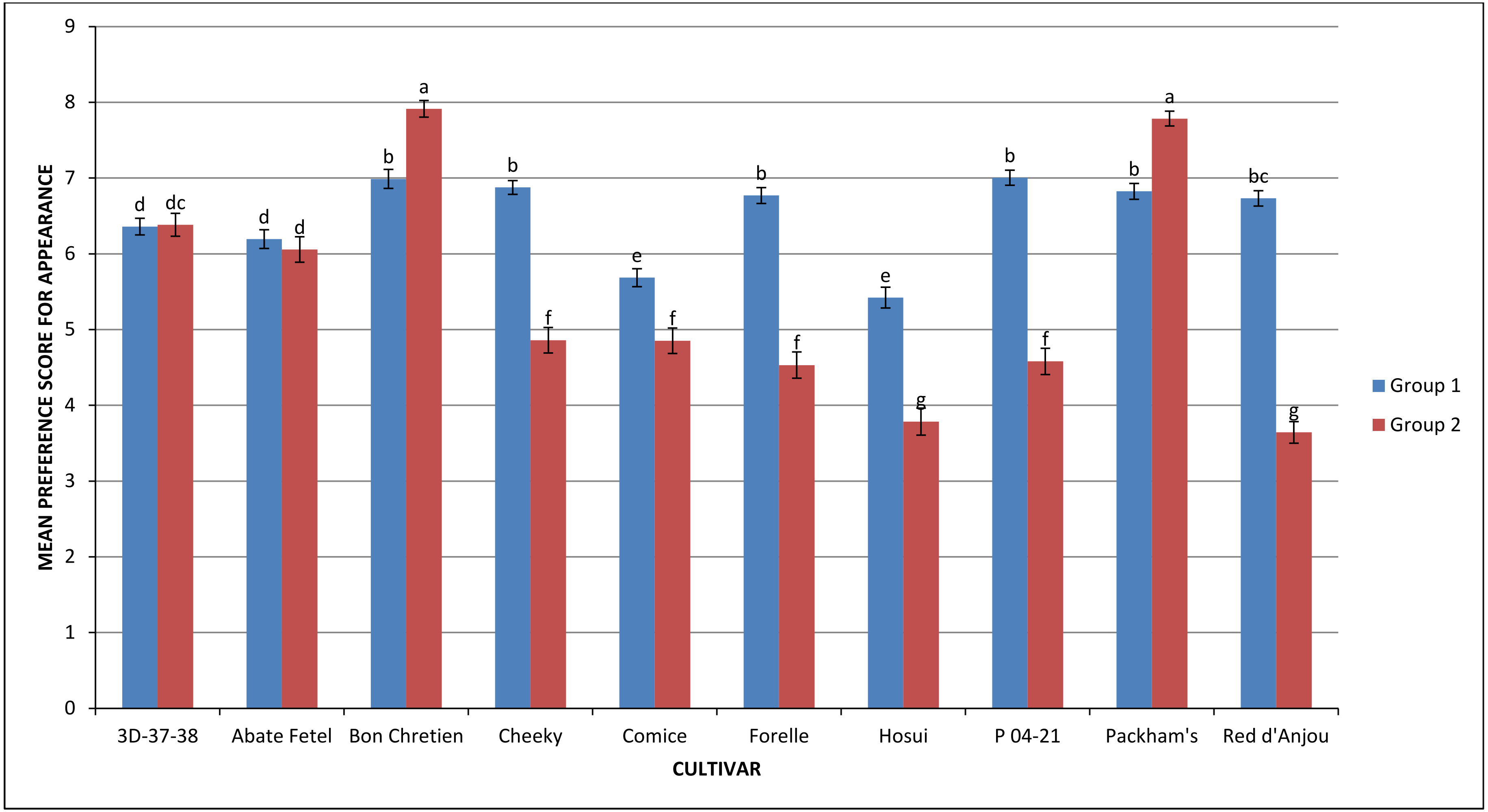

Figure 17. Mean preference scores for pear appearance of consumer groups 1 and 2. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5 % level of significance.

Paper 2: Effect of harvest time and ripeness on consumer preference of 'Forelle', 'Packham's Triumph' and 'Abate Fetel' pear eating quality and appearance

Abstract

The aim of this study was to investigate the effect of harvest time and ripeness on consumer preference for pear eating quality and appearance. Three pear cultivars, viz. Packham's Triumph, Abate Fetel and Forelle, were harvested on two dates one month apart, the first harvest was during the commercial harvest date and the second harvest followed a month later. All fruit were kept in cold storage at -0.5 ºC for four and three months for the first and second harvests, respectively. Harvest one pears (H1) were then ripened at room temperature (20 ºC) for seven days while harvest two pears (H2) were taken out of cold storage the day before each analysis. Physiochemical measurements were taken and sensory attributes assessed for both harvest dates. Then 150 consumers from different ethnic groups recorded their preferences for the taste and appearance of the pears of both harvest dates on a hedonic scale. Principal component analysis (PCA) was performed to project instrumental measurements onto the sensory dimensions to investigate the eating quality parameters that associated with each of the treatments. Two main groups of consumers were identified; group 1 (33% of total consumer group) showed a preference for the characteristics of crispness, hardness and firmness, while the larger number of consumers of group 2 (67%) indicated a positive correlation with melt character, juiciness, overall pear flavour and sweet taste. These last characteristics were the most prominent in first harvest 'Packham's Triumph' pears that were ripened for seven days. Most pear consumers preferred ripe fruit and if the industry could find a way to deliver such a product to them, while still minimising fruit lost due to over ripeness or bruising, the pear industry could regain consumer confidence and expand its market share. There is, however, also a market for crisp pears and 'Forelle' and 'Abate Fetel' could both be suitable for this market as the eating quality of the former was preferred when it was still a firm pear, while there was no overall difference between preference for harvest time or ripening stage of the latter.

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Introduction

A consistent and high eating quality is a prerequisite for consumer satisfaction and for encouraging loyalty to pear cultivar and region of origin (Predieri and Gatti, 2008). The consumption of European pears (*Pyrus communis* L.) in South Africa has declined to less than 1 kg per person per year (Belrose Inc., 2015). When we compare this to a country such as Italy with a 10 kg per year per capita consumption rate, the South African market could potentially grow ten-fold. As consumer satisfaction and loyalty is quickly becoming the basis for guiding production strategy development, fruit quality is becoming more important for the pear industry (Predieri and Gatti, 2008). For decades farmers have grown pears and then relied on marketing agents to find countries, retailers and customers that desire their product enough to pay a price that will not only cover expenses, but ensure a decent profit for everyone in the production chain. Cultivars have been selected based on orchard-oriented criteria such as disease resistance, high yields and long shelf-life. These are important criteria, but of even greater importance are those product attributes that will entice consumers to buy the fruit and become regular buyers of pears (Belrose Inc., 2015).

Fruit quality is not easily defined as it is a combination of physical and chemical attributes, both internal and external to the fruit (Kader, 1999). Quality control through sensory analysis and consumer tests, provide an authoritative source for understanding trends of consumer purchase behaviour and should find more application in the production planning of the pear industry (Predieri and Gatti, 2008). Where consumer acceptance is concerned, consistency of eating quality, as well as the level and balance of sensorial traits are very important (Predieri and Gatti, 2008). Cliff *et al*. (1996) stated that initial purchase by consumers is based on visual product attributes, while repeated sales are based on product eating quality. Eating quality, and therefore also consumer acceptance, is greatly influenced by the state of maturity of a fruit (Soliva-Fortuny *et al.,* 2004). Maturity at harvest has a direct effect on the period for which pears can be stored without losing quality (Kader, 1999) and it also affects the ripening potential (Kader, 1999; Crouch *et al*., 2005). The flavour of European pears is complex and depends on a delicate balance of sugars, acids, phenolic and aromatic compounds (Bell *et al.,* 1996), with a number of additional factors, principally texture, also playing a role (Eccher Zerbini, 2002). Fruit ripening processes are very important as they influence the changes that occur during fruit storage, transport and shelf-life, such as softening, sweetening and changes in aroma and colour, as well as affecting nutritional value (Salvador *et al.,* 2007). Fruit potential for high

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quality at consumption is heavily determined by pre-harvest and post-harvest conditions (Sugar *et al.,* 1998).

'Forelle' pears grown in South Africa for the European and UK market have a mandatory cold storage period of 12 weeks at -0.5 ˚C after harvest, as they are prone to astringency and mealiness after shorter storage durations. Mealiness, where pear flesh is characterised by low extractable juice content, is the key internal quality disorder associated with the sensory quality of 'Forelle' pears in South Africa (Carmichael, 2011; Crouch, 2011; Martin, 2002). This required storage period can result in a break in the availability of South African bi-colour pears on the European market, opening a gap for our southern hemisphere competitors to step in, e.g. Chile, where 'Forelle' pears are packed and shipped immediately after harvest (Crouch and Bergman, 2013). The 'Forelle' early market access programme (FEMA) has been researching the possibility of entering the European, UK and Middle Eastern markets by week 15, after only 4 - 6 weeks of cold storage. In order to do this while maintaining fruit eating quality, pears are left to ripen on the tree for 3 – 4 weeks longer after commercial harvest and subsequently treated with 1-methylcyclopropene (1-MCP; Smartfresh™ AgroFresh Inc., Rohm & Haas Company, Philadelphia, PA) to inhibit further ripening and softening. These fruit are then aimed at a target market that prefers crisp and sweet pears (Crouch and Bergman, 2013). Previous research by Moya-León *et al.* (2006) found that pears harvested later than commercial timing and then treated with 1-MCP, followed by cold storage for 4 – 6 months, maintained textural characteristics preferred by consumers, i.e. a soft texture and the capacity for volatile production, suggesting that this technology could be used to maintain fruit quality during long term storage. However, 1-MCP treated pears stored for only 2 months did not ripen and volatile production was inhibited (Moya-León *et al.* 2006), thereby limiting the eating quality characteristics preferred by the consumers.

This study investigated the preference of consumers of different ethnic groups in the Western Cape, South Africa for the eating quality and appearance of pears of three cultivars that were harvested at commercial maturity and ripened for 7 days at 20 ºC to achieve a soft texture and strong pear flavour compared to pears that were harvested a month later and further ripened for only 1 day at 20 ºC to achieve a product that is firmer, but sweet, similarly as when treated with 1-MCP. This latter treatment was thus aimed at simulating the eating quality characteristics of pears in the FEMA programme. Although our study did not include 1-MCP treated fruit, the effect of harvest time and level of ripeness on sensory characteristics were investigated. Previous consumer studies

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conducted in South Africa indicated cross-cultural differences in preference with regard to apple eating quality (Van der Merwe, 2013), which is why we investigated whether this was also the case for pears.

Materials and methods

Plant material

Three pear cultivars were selected for this study, viz. Packham's Triumph, Abate Fetel and Forelle. Pears were harvested at Glen Fruin farm in the Elgin area of the Western Cape, South Africa (latitude: 34°10' S, longitude: 19°10' E). The first harvest (H1) took place on 14 February 2013 at an average flesh firmness of 6.6 kg, 6.3 kg and 6.2 kg for 'Packham's Triumph', 'Forelle' and 'Abate Fetel', respectively, as measured using a penetrometer [Fruit Texture Analyser; GUSS Manufacturing (Pty) Ltd., Strand, South Africa] fitted with a 7.8-mm diameter probe. Two equatorial readings were taken on opposite, pared sides of each pear. The farmer left 2 rows of trees of each cultivar unharvested during the first (commercial) harvest (H1) and on 13 March 2013, a second harvest (H2) took place at an average flesh firmness of 5.6 kg, 5.9 kg and 4.6 kg for 'Packham's Triumph', 'Forelle' and 'Abate Fetel', respectively, and fruit where harvested randomly from any position on these trees.

Experimental design

A total of 222 fruit were used, 74 per cultivar with 37 fruit for each harvest date. Of these, three representative fruit per harvest date per cultivar were used for photographs of which one was selected to measure consumer liking for appearance, five fruit for physicochemical analyses and firmness measurements (1 fruit for each of five replicates), four for descriptive sensory analysis (1 fruit for each of four replicates) and 20 fruit were used for the consumer preference testing.

All fruit were kept in cold storage in regular atmosphere (RA) at -0.5 ºC at the Department of Horticultural Science, Stellenbosch University, South Africa for four and three months for the two harvests, respectively. Harvest one (H1) was then ripened at room temperature (20 ºC) for seven days while harvest two (H2) was taken out of cold storage the day before physicochemical and sensory analyses and consumer preference assessment commenced.

Physicochemical measurements

Instrumental analyses were conducted on 21 June 2013 using five fruit from each harvest date. Different fruit from the same cultivars were thus used for descriptive sensory analysis (DSA) and instrumental measurements.

Fruit firmness (kg) was determined as the maximum force required to push a 7.9 mm diameter probe with a convex tip into the flesh, after peeling two equatorial sites, using a motorised penetrometer [Fruit Texture Analyser; GUSS manufacturing (Pty) Ltd., Strand, South Africa].

Slices of pear were placed in a juice extractor and the juice from each sample was used to determine the total soluble solids (TSS) concentration with a digital refractometer (TSS 0-32%, Model N1, Atago, Tokyo, Japan) and titratable acidity (TA) using an automated titrator (Tritino 719S and Sample Changer; Metrohm Ltd., Herisau, Switzerland) by titrating 10 g of juice from each pear with 0.1 M NaOH to a pH endpoint of 8.2. TA results were expressed as percentage malic acid. The TSS:TA ratio was calculated for all samples. Average values per treatment were calculated and used for further statistical analyses.

The incidence of mealiness was evaluated after seven days of ripening at room temperature (20 °C) for H1 and 24 h at room temperature for H2 fruit. Longitudinal wedges (± 1/6th of fruit) were cut from each of the pears. The wedges were evaluated for mealiness, as well as squeezed to assess free juice. Fruit with a dry, coarse, floury texture were classified as mealy. The same evaluator assessed mealiness of all samples.

Percentage dry matter concentration (DMC) was determined by weighing a fresh pear sample and oven drying the sample over a period of 72 h at 45 °C. The pear sample was weighed, returned to the oven for another 24 h and re-weighed to ensure that all the moisture had evaporated. The percentage DMC was calculated as dry weight as a percentage of fresh weight.

Descriptive sensory analysis

DSA was performed in June 2013 in the sensory research laboratory at the Department of Food Science, Stellenbosch University, South Africa. The sensory panel consisted of eight female judges. All judges were experienced in sensory analysis of pears and were therefore only subjected to four training sessions. Training was conducted using the DSA consensus method and analyses were performed as described by Lawless and Heymann (2010). Judges were tested for consistency using PanelCheck (Nofima, Norway). Samples of all three cultivars and both harvests were used in the training sessions to calibrate the panel on the sensory attributes to be tested. Unstructured line scales were used for attribute intensity scaling. The left hand side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity. The judges agreed on a consensus list of attributes for describing the flavour and texture of the peeled pear samples, viz. sour taste, sweet taste, overall pear flavour, crispness, crunchiness, juiciness and mealiness. It was also decided to analyse the attributes of “astringency” and “bitterness” of the unpeeled samples. The definitions used for the sensory attributes (Table 1) were similar to those used by Daillant-Spinnler *et al.* (1996).

The fruit were analysed during four replicate sessions. The panel assessed one fruit of all three cultivars and both harvest dates during a replicate session. Pears were cut lengthwise, stem to calyx, into eight slices so that the same pear was analysed by the entire panel during a replication. Slices of unpeeled fruit were presented on Petri dishes (Kimix, South Africa) and panellists were instructed to cut the samples in half (lengthwise) and peel one of the resulting pieces prior to analysis of the flavour and texture attributes, respectively. Samples were coded with three-digit random codes and presented in a randomised complete block design, balanced to minimise order and carry-over effects. The latter design was based on the Williams Design presented by the Compusense® *five* data collection software system that also collected the data electronically (Version 4.2, Compusense Inc., Guelph, Ontario, Canada). Distilled water and unsalted, fat-free biscuits (Woolworths, Cape Town, South Africa) were provided as a palate cleanser between samples. Profiling was conducted in tasting booths with standardised artificial daylight lighting and temperature control (21 ºC). The average intensity over replicates and assessors for all attributes were computed and used in the univariate and multivariate data analyses (Johansen *et al.*, 2010).

Consumer preference

Consumer preference tests were conducted in the Langenhoven Student Centre, Stellenbosch University, South Africa on 20 June 2013. Hundred and fifty (N = 150) consumers were recruited on the basis that they consume pears on a regular basis. White consumers were mainly recruited from Stellenbosch University, and were either students or staff. Coloured and black students and staff from Stellenbosch University also participated in this study, but in order to include a representative sample from the larger Stellenbosch area, coloured consumers were further recruited from Cloetesville, a

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predominantly coloured suburb of Stellenbosch and black consumers from Kayamandi, an informal settlement on the outskirts of Stellenbosch.

The recruited consumers were asked to complete a questionnaire that captured socio-demographic information (i.e. gender, age, ethnic group, fruit consumption frequency and specifically pear consumption frequency), as well as preferences for eating quality and appearance.

Preference for eating quality

Consumers were presented with unpeeled samples of all three cultivars of both harvest dates. A randomised complete block design was used, balanced for order and carry-over effects and similar to the design used for the descriptive sensory analysis. Consequently, every eight consumers received a sample set of the exact same fruit, while different fruit from the same cultivars were randomly selected from a box and given to the next set of eight consumers. Consumers rated each sample for liking of eating quality on a nine-point hedonic scale from "*dislike extremely*" to "*like extremely*". In this test, consumers were asked to indicate which term best describe their attitude towards the products being tasted (Lawless and Heymann, 2010). Consumers were instructed to indicate their preference for the total eating experience, including texture and flavour. Samples were coded with three-digit random codes and served in Petri dishes on white trays in a room with standardised artificial daylight lighting and temperature control (21 ºC). Consumers were requested to drink water between samples to refresh their palate.

Preference for appearance

To investigate consumer preference for appearance photographs of one representative pear of each of the three cultivars of both harvests were taken on 18 June 2013 by Stellenbosch University photographic services. Thus the pictures were taken after cold storage and after ripening for 7 and 1 day at 20 ºC for H1 and H2 fruit, respectively. This was two days before consumer testing commenced (Figure 1). Consumers were presented with these, almost life-size, photographs and requested to use the nine-point hedonic scale to indicate their liking for the overall appearance of the cultivars on the photographs provided. The different aspects of appearance i.e. shape, colour and russet was all integrated under appearance. A randomised complete block design was again used, where all consumers analysed all six photographs.

Statistical procedures

The purpose of the consumer study was to analyse the preference of Western Cape consumers of different ethnic groups for the appearance and eating quality of pears of three cultivars that were harvested at commercial maturity, stored at -0.5 ºC for 4 months and ripened for 7 days at 20 ºC compared to pears that were harvested a month later, stored at -0.5 ºC for 3 months and further ripened for only 1 day at 20 ºC. Instrumental and sensory data were included in the statistical analysis to serve as an external data set to further explain the intrinsic factors that drive consumers' pear preferences. Cultivars were analysed separately as our objective was not to compare cultivars.

Physicochemical analysis data (5 replications) for firmness, DMC, TSS, TA and TSS:TA were subjected to one-way analysis of variance (ANOVA) by general linear models (GLM) using Statistica version 12 (StatSoft Inc., Tulsa, OK) with cultivar as main effect. As there was no incidence of mealiness, no statistics were performed for that attribute. Student's t-Least Significant Difference was calculated at the 5% significance level to compare treatment means. The Shapiro-Wilk test was performed on the residuals to test for non-normality (Shapiro & Wilk, 1965). If non-normality was significant ($P \leq 0.05$) and caused by scewness, the outliers were identified and removed until the data were normally or symmetrically distributed. The final analysis of variance (ANOVA) was performed after the pre-processing procedures had taken place.

The sensory data for each attribute were subjected to a three factor analysis of variance (ANOVA) with harvest time, panellists and replications as main effects using Statistica version 12 (StatSoft Inc., Tulsa, OK). No significant interaction ($P \leq 0.05$) was found, indicating that the mean scores gave a reliable estimate of the samples' sensory attributes per cultivar. Cultivar attributes were therefore averaged across replicates and panellists.

For consumer preference data, a complete randomised design was used. ANOVA was performed on the consumer data to establish if there was a difference in the consumer preference for pears with regard to eating quality and appearance for different ethnic groups using Statistica version 12 (StatSoft Inc., Tulsa, OK).

Consumers can be grouped based on socio-demographic characteristics (Thybo *et al.*, 2003) or on similar preference patterns (Daillant-Spinnler *et al.*, 1996; Carbonell *et al.*, 2008). To identify potential consumer groups that form clusters with a similar preference pattern for eating quality, Ward's hierarchical cluster analysis was performed on the residual data. Having identified two main groups, 33% of consumers in group 1 and 67% in group 2, from the dendrogram (Figure 2), K-means clustering was then performed on the two groups. Establishing that there is a good correlation between the two methods of clustering, it was decided to continue using the K-means method for further analysis. Multivariate statistical analysis was employed (XLStat, Addinsoft, France) to investigate the possible relationships between physicochemical data, descriptive sensory data and consumer preference data, e.g. Principal Component Analysis (PCA). Principal Component Analysis (PCA) was carried out to identify variables that associate with certain treatments (Rencher, 2002). PCA is a projection method that assists one to visualize all the information in a data table; it provides a tool to find patterns and relationships between samples and several variables simultaneously. XLStat software (Addinsoft, France) was used to perform Pearson's correlation between sensory and physicochemical measurements.

Results

For the purpose of this part of the study and in order to refrain from vague terms for reporting, "*preference for eating quality*" indicates a consumer's degree of liking for the overall texture and flavour of pears, where the term "flavour" includes sweet taste, sour taste, as well as pear aroma (Rowan *et al.*, 2009). "*Preference for appearance*" indicates how consumers liked the overall appearance of the fruit. For the sake of readability and brevity, only the most important differences in sensory and instrumental sample attributes will be reported.

Physiochemical measurements

The mean firmness of H1 'Forelle' fruit that was allowed to ripen for seven days after cold storage was 2.7 kg while H2 fruit was firmer at 5.1 kg (Table 2). 'Forelle' H1 fruit was significantly higher in total soluble solids (TSS) at 16.6 °Brix than H2 at 15.0 ˚Brix. 'Forelle' H2 had a significantly higher level of titratable acidity (TA), with a mean of 0.23%, while H1 measured 0.17%. Neither the TSS:TA ratio, nor the dry matter concentration percentage (DMC) for H1 was significantly higher than that of H2 (Table 2). No mealiness was observed (data not presented).

'Packham's Triumph' H1 fruit had a mean firmness of 1.1 kg, while H2 fruit had a significantly higher mean of 5.4 kg (Table 2). 'Packham's Triumph' H2 had a higher TSS (15.9 ˚Brix) than the H1 fruit (14.1 ˚Brix). H2 'Packham's Triumph' fruit also had a significantly higher TA of 0.20%, while H1 fruit had a mean TA of 0.13%. The TSS:TA ratio for H1 was not significantly higher than H2 and there was no difference in DMC between harvests.

'Abate Fetel' H1 had a mean fruit firmness of 2.3 kg while H2 fruit was significantly firmer at 4.0 kg (Table 2). 'Abate Fetel' showed no significant difference between harvests for TSS, but H1 had a significantly higher TA of 0.09 % compared to 0.06 % for H2. H2 had a TSS:TA ratio of 224, significantly higher than H1 with 151. There were no significant differences in DMC between harvests.

Sensory attributes

DSA was conducted using four replicate sessions; the panel of judges thus analysed four pears per treatment. This resulted in a mean intensity value for each attribute, as depicted in Table 3.

'Forelle' H2 was significantly harder with a score of 59 on a scale of 0 - 100, compared to 22 for the ripened H1 pears. Overall pear flavour and TSS did not differ significantly between harvest times. H1 scored significantly higher than H2 for sourness (21 vs. 16), melt character (33 vs. 6), astringency with peel (17 vs. 5), astringency without peel (18 vs. 3) and grittiness (19 vs. 15). H1 scored 43 for juiciness while H2 scored significantly higher at 52 (Table 3). No bitterness was observed in fruit from either harvest (data not presented).

'Packham's Triumph' H1 fruit were significantly softer than H2 fruit (12 vs. 59), but higher in overall pear flavour (77 vs. 51), sweet taste (71 vs. 53), melt character (75 vs. 5) and juiciness (74 vs. 59) (Table 3). H1 fruit scored slightly lower than H2 fruit for sour taste (18 vs. 21), astringency with peel (2 vs. 10) and astringency without peel (1 vs. 6). The level of grittiness was the same for both harvests (Table 3) and no bitterness was detected (data not presented).

In **'Abate Fetel'**, H2 fruit was significantly harder than H1 fruit (57 vs. 32) while H1 fruit was significantly higher in pear flavour (61 vs 49) and melt character (39 vs. 6) (Table 3). There was no significant difference in sweetness, sourness, juiciness and astringency between H1 and H2 fruit. H1 pears were slightly, but significantly grittier than H2 (19 vs. 16). No bitterness was observed (data not presented).

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Consumer preference of total group of consumers

Consumer socio-demographic information

The black, white and coloured consumers constituted 23 (15.4%), 62 (41.6%) and 64 (43%) of the total consumer group (N=150), respectively. Hundred (N=100) consumers were female and 50 were male.

Consumer preference for eating quality and appearance

Consumers on average preferred the overall eating quality of H2 fruit for ‘Forelle’ and H1 for ‘Packham’s Triumph’, while there was no difference in preference for eating quality between H1 and H2 fruit for ‘Abate Fetel’ (Table 4). Consumers preferred the appearance of H1 fruit for ‘Forelle’ and ‘Packham’s Triumph’, while ‘Abate Fetel’ H2 fruit were visually more appealing to consumers than the H1 fruit.

Preference based on ethnicity

There were no significant differences for preference of eating quality between harvest times amongst ethnic groups with regard to ‘Forelle’ (Table 5). ‘Packham’s Triumph’ also showed no differences between ethnic groups and all three ethnic groups followed the same trend of preferring H1 fruit while in ‘Forelle’ they preferred H2 fruit. With regard to ‘Abate Fetel’, H1 fruit were preferred significantly more than H2 by coloured consumers, while the other two ethnic groups equally liked fruit from both harvests.

There were no significant differences between ethnic groups for preference of appearance between harvest times for ‘Forelle’ but overall the appearance of H1 fruit was preferred by all ethnic groups (Table 5). The appearance of ‘Packham’s Triumph’ H1 was preferred significantly more than H2 by both white and coloured consumers groups, while black consumers liked the appearance of both harvests equally. There was no difference in the liking of all three ethnic groups for H1 appearance. For ‘Abate Fetel’, the appearance of H2 was preferred significantly more than that of H1 fruit by all ethnic groups although the preference of black consumers for H2 was not significantly higher than the preference of coloured consumers for H1.

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Cluster analysis of consumer preference data

Eating quality preference patterns of two consumer groups

The cluster analysis indicated two distinct groups that differed in their preference for different eating quality attributes. The sensory and instrumental drivers of consumer liking of eating quality of these two groups are illustrated in Figure 3. This PCA correlation plot illustrates the association of liking scores for eating quality of the individual consumers with the sensory attributes and instrumental firmness of pears. Group 1 (49 people, 33% of consumers on the right side of the correlation plot) had a positive correlation with sensory hardness and instrumental firmness, clearly indicating that consumer group 1 consumers like a firm, hard pear. Group 2, however, (101 people, 67% of consumers) showed a positive correlation with the sensory attributes associated with ripe, soft-eating pears, i.e. melt character, overall pear flavour and sweet taste. This indicates that two thirds of the consumers in this experiment gravitated towards soft-eating pears. According to the correlation plot, grittiness plays no part as a driver of liking, primarily because the reliability is <50% as it falls within the inner circle. Astringency and sour taste, although indicated by the correlation plot as important negative drivers of consumer preference for pears, do not cause segregation between groups 1 and 2. Likewise, juiciness seems to be an important positive driver of consumer preference for both groups 1 and 2.

Group 1 consumers indicated that they consume pears more frequently than group 2 while group 2 indicated that they prefer softer pears than group 1 (Table 6). Group 1 consumers gave a similar score for their liking of soft or hard pears. Although not significant (P=0.06), there is a trend suggesting that group 2 tend to prefer juicier pears. Also, there is an indication (p<0.1) that group 1 consumers are slightly younger than group 2 consumers (27 vs. 31 years). There was no significant difference between the perceived preference of the two groups for sweetness or pear flavour. With regard to gender composition, group 1 consisted of 75% female and 25% male consumers while group 2 consisted of 62% female and 38% male consumers. In terms of ethnicity, group 1 had 46% white, 37% coloured and 17% black consumers while group 2 consisted of 40% white, 46% coloured and 15%) black consumers (Table 6).

Consumer group 1 preferred the H2 'Forelle' significantly more than H1 fruit (Table 7) while group 2 preferred H1 'Forelle' significantly more than the H2 fruit. There was no difference in the preference score of group 1 for H2 and group 2 for H1 fruit. The preference of group 2 for H2 fruit was intermediate and higher than the dislike of group 1

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for H1 fruit. Group 2 preferred the H1 'Packham's Triumph' significantly more than H2 fruit, which they gave a similar intermediate score as group 1 gave both harvest dates. For 'Abate Fetel', groups 1 and 2 preferred the H2 and H1 fruit, respectively, and gave similar intermediate scores for H1 and H2 fruit, respectively.

A principal component analysis (PCA) was conducted to determine instrumental drivers of sensory quality and treatment segregation between instrumental and sensory attributes (Figure 4). With regard to the instrumental drivers of sensory quality, the PCA bi-plot (Figure 4) indicates a strong, positive correlation between the sensory attribute of hardness and the instrumental measurement of firmness ($r=0.939$; $P\leq0.05$) (Table 8.). Similarly, DMC (%) correlated strongly with TSS (ºBrix) ($r=0.976$; $P\leq0.05$) as indicated on the right side of principal component 1 (PC1/F1). Interestingly and contrary to expectation, the instrumental attributes TA (bottom right quadrant of PC1), TSS (bottom right quadrant), and the TSS:TA ratio (top left quadrant) did not correlate significantly ($P>0.05$) with the sensory attributes of sour taste and sweet taste, respectively. Sweet taste and overall pear flavour, indicated on the bottom left quadrant of PC1 (Figure 4) correlated strongly ($r=0.843$; $P\leq0.05$). Similarly overall pear flavour and melt character correlated strongly ($r=0.967$; $P\leq0.05$).

The PCA plot explained 74% of the total variation in the data (Figure 4). On PC1, explaining 46 % of the variance, it seems that the basic taste modalities, sour and sweet taste, are the main variables driving this principal component, whereas on PC2, explaining 29 % of the variance, it seems that that variables hardness and melt character can be regarded as the main drivers of PC2. When viewing the % contribution of each variable in the respective PC's (data not shown), this tendency is not clear-cut. H1 and H2 pears of all three cultivars, but Forelle and Packham's Triumph in particular, segregated on PC2 while H1 and H2 'Packham's Triumph' also separated on PC1. 'Forelle' H2, positioned in the top right quadrant, associated strongly with instrumental firmness and sensory hardness, whereas 'Forelle' H1 associated strongly with the sensory attributes of sourness and astringency. 'Forelle' H2 appears to correlate negatively with melt texture and sweet taste. 'Packham's Triumph' H1, bottom left quadrant, associated strongly with melt character and pear flavour, while 'Packham's Triumph' H2 associated strongly with instrumental firmness and sensory hardness, as positioned in the top right quadrant. 'Abate Fetel' H1 and H2, both positioned in the top left quadrant of Figure 4 did not correlate strongly with any attribute besides the instrumental attribute of TSS:TA ratio.

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Consumer groupings for appearance liking

Group 1 scored the H1 'Forelle' pears significantly higher on the 9-point hedonic scale at 8.1 than H2 at 6.9, while group 2 scored H1 and H2 similarly 6.9 and 6.7, respectively (Table 7). Both consumer groups 1 and 2 scored H1 'Packham's Triumph' fruit higher for appearance liking with scores of 7.2 and 7.3 respectively, group 1 scored the H2 fruit significantly lower than group 2 at 5.5 compared to 6.6, although it is still significantly lower than their score for H1. Group 1 scored 'Abate Fetel' much lower for liking of appearance for both harvest times with a mean of 3.7 for H1 fruit, and H2 fruit significantly higher at 5.3. Group 2 scored the appearance liking of 'Abate Fetel' significantly higher than group 1 for both harvests. In addition, group 2 scored H2 fruit significantly higher than H1, at 7.1 compared to 6.5.

Discussion

It is evident from this research that harvest maturity, storage duration and ripeness have a significant effect on the sensory and physicochemical attributes of pears and thus ultimately consumer preference. The firmness and sensory hardness of H1 fruit were significantly lower, and melt character significantly higher than H2 fruit for all three cultivars while the DMC levels were unchanged between harvests. Other differences were not consistent between cultivars and may be the reason for differences in consumer preference for H1 or H2 fruit, indicating that preference for pear eating quality can be cultivar specific.

'Forelle' H1 fruit that was allowed to ripen for seven days after cold storage was significantly softer than H2 fruit that were left on the tree for an additional month and only allowed 1 day of ripening. Although H1 was higher in TSS and lower in TA than H2, the TSS:TA ratio for H1 was not significantly different to that of H2. The TSS:TA ratio explains the sweet and sour balance in pears. A relatively high ratio is required for the right sweet and sour balance to occur (Chen *et al*., 2007). While H1 had a lower TA value, it scored significantly higher for sour taste. This seems counterintuitive, but could be due to the higher levels of astringency observed in H1. Theoretically the two attributes are analysed independently by the sensory panel, but practically, the two attributes may sometimes be hard to separate during analysis as non-phenolic organic acids (e.g. citric and malic) can elicit astringent sensations in addition to a sour taste (Bajec and Pickering, 2008). Lawless *et al.* (1996) states that the astringency caused by acids decreases along with the increasing pH and concurrently, decreases in the sourness of these compounds also occur; this indicates a strong interdependence between these properties (Laaksonen, 2011). Figure 4 illustrates how sour taste, as well as astringency, correlated strongly with 'Forelle' H1 fruit. Mielke and Drake (2005) found that the incidence of astringency in pears is related to the degree of maturity of the fruit with immature fruit being more astringent due to higher tannin levels. In this research, astringency was higher in the H1 fruit that ripened for seven days, which seems contrary to previous findings, but it could be that 'Forelle' H1 was harvested at a lower physiological ripeness and therefore retained the astringency of unripe pears although it was allowed to shelf ripen. Previous experience with climacteric fruit has shown that unripe fruit will have poor sensory quality (Peirs *et al*., 2001).

This research simulated trials done by the 'Forelle' FEMA programme. The FEMA programme suggests the possibility of shortening the 12 week mandatory cold storage period 'Forelle' pears are currently subjected to before export (Crouch and Bergman, 2013). This is done by allowing pears to mature on the trees until they have reached a TSS of at least 14 ºBrix and flesh firmness between 6.0 and 5.5 kg. Directly after harvest, fruit are subjected to the ripening inhibitor SmartFresh^{TM} (1-methylcyclopropene), then immediately packed into 20 µm low density polyethylene (LDPE) bags, and shipped to reach offshore markets by week 15. Fruit ripening is retarded by SmartFresh^{TM}, thereby eliminating mealiness and resulting in a crispy, sweet pear. Crouch and Bergman (2013) found that later harvested 'Forelle' can be marketed as "Crisp and Sweet" within 4 to 6 weeks of harvest if SmartFresh^{TM} application is used at harvest. Our research provides supports for the FEMA programme, as the consumers in our trial on average preferred the H2 pears; the reality is more complex however. Group 1 consumers indicate their likes and dislikes strongly by scoring either very low, i.e. H1 at 3.4 or high H2 at 7.3 (Table 7) while group 2 consumers gave more intermediate scores for H1 at 6.9 and H2 at 5.7. So, while group 1 only represents 33 % of all the consumers, the scores they gave had a large influence on the average scores. Since group 2 represent 67 % of total consumers and they scored H1 higher than H2, it would also be true to say that most consumers prefer H1. It should also be noted that H2 fruit was not treated exactly according to FEMA protocol – FEMA fruit tend to be firmer (Crouch and Bergman, 2013).

Previous studies showed that high acidity coupled with low sugar content would generally result in low consumer acceptability (Boylson *et al*., 1994). In this research, even though the acidity was not higher and sweetness was the same for both harvests, the taste of H1 fruit was perceived as more sour, possibly due to high levels of astringency, and thus H1 fruit on average scored lower for consumer preference than the H2 pears. H1 fruit had higher levels of the desirable attributes of juiciness and melt character, according to the sensory analysis; however, consumers on average indicated a preference for the H2 fruit that had the same level of sweetness, but a significantly harder texture and lower levels of astringency and sourness. Although there were no significant differences between ethnic groups, there is a slight trend showing that white and black consumers prefer the harder 'Forelle' pears, while coloured consumers liked H1 and H2 fruit equally.

With regard to appearance, H1 pears were preferred to H2. Consumer liking of eating quality and liking of appearance scores correlated well for H2 fruit, while H1 fruit scored high for appearance, but received a much lower average score for eating quality (Table 4). It is possible that H2 fruit did not comply with industry's prerequisite colour requirements

'**Packham's Triumph**' is the most important pear cultivar grown in South Africa covering 32% of total pear production (HORTGRO, 2014). Two of the main postharvest problems of 'Packham's Triumph' pears are premature yellowing and flesh softening, especially during long term storage (Manriquez, *et al*., 2011). In recent years, 1-MCP has been evaluated as a tool for postharvest management in different climacteric fruits including pears (Argenta *et al*., 2003; Trinchero *et al*., 2004; Watkins, 2006). The application of 1-MCP in 'Packham's Triumph' pear effectively controlled ripening; however, its effect is quite strong and in some cases the fruit take a long time or never reaches a ready-to-eat stage, especially when the application is performed immediately after harvest (Manriquez *et al*. 2011). As consumers scored H1 pears significantly higher than H2, this research suggests that as a cultivar, Packham's Triumph might not be suitable for treatment with SmartFresh^{TM} if this means that fruit never ripen properly. H1 pears that were harvested earlier, but ripened for 7 days were significantly softer, higher in TSS and lower in TA than H2 fruit. Overall pear flavour, sweetness, juiciness and melt character was also significantly higher in H1 fruit. All these characteristics, but especially pear flavour, are important factors for eating quality of pears and can be regarded as important drivers of consumer liking (Eccher Zerbini, 2002). This is confirmed by the correlation between the preference of group 2 (67% of consumers) with the characteristics of overall pear flavour, sweetness, juiciness, and melt character (Figure 3). Group 1 consumers did not seem to like the eating quality of this cultivar regardless of whether it is firm or soft, while group 2 did not differ from group 1 in their indifference towards H2 pears, but had a strong preference for H1. Since group 2 represents 67% of consumers, there is on average a large preference for H1 pears of this

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cultivar. H2 was significantly higher in astringency and this, given the fact that the intensity for astringency was very low, could possibly have had a negative impact on consumer preference. It would be interesting to determine through further trials, whether H2 fruit ripened for 7 days are higher in these important characteristics that drive consumer preference. Allowing pears to ripen for a few days after harvest and then treating them with 1-MCP could be another possible option to obtain the storage quality benefits from 1-MCP treatment while also attaining good eating quality. This idea is supported by research done by Moya-León *et al*. (2006), where 'Packham's Triumph' pears from a late harvest date were treated with 1-MCP and proved capable of producing higher levels of volatile compounds during storage than those harvested during the commercial peak. These 1-MCP treated pears also maintained textural characteristics preferred by the consumers and therefore this technology could be used for maintaining fruit quality during long-term storage. With regard to appearance, black consumers made no distinction between H1 and H2 fruit, while white and coloured consumers significantly preferred the appearance of the H1 pears. Consumer groups 1 and 2 both preferred the appearance of H1. For this cultivar then, the eating quality as well as the appearance of H1 fruit was preferred.

'**Abate Fetel'** showed no significant difference between harvests for TSS, sweetness, sourness or juiciness, but H1 had a significantly higher level of TA and were also significantly higher in pear flavour and grittiness, while it was significantly lower in hardness. Grittiness is generally thought to be a negative characteristic in pears (Jaeger *et al*., 2003), but at the low levels present, did not affect consumer preference for eating quality. H2 was higher in hardness with no perceivable melt character and had a significantly higher TSS:TA ratio than H1. The TSS:TA ratio explains the sweet and sour balance in pears (Eccher Zerbini, 2002). For the preferred sweet and sour balance to occur, a relatively high level of both is required (Chen *et al*., 2007). In previous research done by Zerbini *et al*. (2005) on the effect of 1-MCP on pears, it was found that 'Abate Fetel' showed a higher ethylene production rate during shelf-life and were less sensitive to 1-MCP dose than 'Conference' pears. Fruit of this cultivar also softened during shelf-life regardless of the 1-MCP dose and the time. After 3 months in RA, the 1-MCP-treated fruit had a good flavour and a better texture than control fruit, which softened with a firm texture and a watery taste. 1-MCP was also effective in reducing superficial scald in this cultivar. Our data suggest that 1-MCP could be a useful tool for this cultivar.

Consumers seemed to like both harvest times and levels of ripeness equally. This is similar to previous research done by Predieri and Gatti (2008) finding that harvest date did not affect Abate Fetel eating quality, probably because this late ripening cultivar has a wide harvest period. There was also no significant difference in TSS between H1 and H2. Group 1 consumers, however, preferred H2 fruit while group 2 preferred H1 fruit. The preferences of the two consumer groups balance each other to such an extent that there seems to be no preference between harvests. As group 2 represent 67% of consumers, it would logically follow that the industry should focus on their preferences; Table 6 indicates that group 1 consume more pears than group 2, but not even double the amount of group 2 and group 2 is twice the size of group 1. Although there was no pronounced difference in preference between first and second harvest 'Abate Fetel', black consumers scored H2 significantly higher than coloured consumers. On average consumers preferred the appearance of H2 pears.

While two distinct consumer groups were identified, gender and ethnicity did not seem to influence inclusion in the groups as the differences were not statistically significant. Hence, the demographic factors responsible for these groupings are thus as yet undefined. This is different from the clear differences in preference for apple eating quality and appearance for white, coloured and black consumers in the Western Cape found by Van der Merwe (2013). Flavour attributes were important drivers of liking of apple eating quality for the coloured and black consumers, whose preferences differed from those of white consumers on average. Coloured and black consumers' preference manifested in high liking scores for cultivars with high sweetness and low sour taste (Van der Merwe, 2013). Approximately 30% of South Africa's total apple production is sold fresh locally (HORTGRO, 2014) and 29% of the crop exported to the rest of Africa. Only 2% of pears are currently exported into Africa and low levels are consumed locally (HORTGRO, 2014). As black consumers dislike sourness and acidity is considerably lower in pears than in apples, so much so that it may be undetectable as a component of taste (Jackson, 2003), it could explain why there are no clear differences between ethnic groups for preference for pear eating quality. Black consumers scored pears of suitable eating quality quite high; this might indicate a growth opportunity for the industry.

Conclusions

This study simulated the FEMA programme, where 'Forelle' pears are allowed to tree-ripen to compensate for their inability to respond to ethylene as a ripening agent after the application of 1-MCP at harvest. These pears are then marketed as "crisp and sweet" compared to the traditional soft and melty texture that ripe European pears attain. FEMA pears, however, may be firmer with higher levels of TA, TSS: TA and pear flavour than the ones used in this study.

Our results indicate that 'Forelle' is suitable for this treatment, as consumer preference of the Western Cape Province is aligned with the eating quality characteristics of later harvested, i.e. more mature, but less shelf ripe, 'Forelle' pears. Western Cape Province consumers generally do not like the eating quality characteristics of later harvested, but less shelf ripe 'Packham's Triumph' pears. Hence, 'Packham's Triumph' does not seem suitable for 1-MCP treatment as it would inhibit the eating quality characteristics that consumers favour for this cultivar. However, ripening 'Packham's Triumph' to a ready-to-eat stage and then treating it with 1-MCP to stop further ripening and postharvest quality deterioration could offer a solution (Moya-León *et al.* 2006). While Western Cape Province consumers indicated no preference between early harvested and shelf-ripe compared to later harvested but less shelf ripe 'Abate Fetel' pears, research done by Zerbini *et al*. (2005) indicated possible benefits for treating this cultivar with 1-MCP as it allows fruit to retain flavour and good texture during cold storage while lowering the incidence of superficial scald. A possible problem with the use of 1-MCP for this cultivar is its slowing of background colour development, as this research shows that Western Cape Province consumers prefer the appearance of ripe pears. However, the pears also need to meet certain colour standards on the local market and will be rejected or downgraded if too yellow. Some level of yellowing on the tree and slowing further yellowing with 1-MCP treatment might therefore provide fruit with a more acceptable colour.

It is interesting to note that pears were still within commercial firmness ranges at the second harvest a month after the H1 pears were commercially harvested. However, fruit may have been rejected due to advanced yellowing. Studies have shown that fruit harvested later in the picking window develop higher levels of volatiles (Zerbini and Spada, 1993), are lower in TA and higher in TSS:TA ratio (Mielke *et al*., 2005). To assess the effect of harvest maturity on pear eating quality characteristics and consumer preference, future studies could assess pears harvested at different times, but with standardised storage and ripening duration. As the sample size was small and it is only group 1 and 2 that had reasonable numbers, it is suggested that the study be repeated with more consumers to test the reliability of the results.

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Table 1 Terminology for descriptive sensory analysis (Source: Daillant-Spinnler *et al.*, 1996).

Attributes	**Description**	**Scale**
Overall pear flavour	Aromatics of typical pear	0= None ; 100=Very strong pear flavour
Sweet taste	Basic taste caused by characteristic sugars, e.g. sucrose	0= None ; 100=Prominent sweet taste
Sour taste	Basic taste caused by characteristic acids, e.g. citric acid	0= None ; 100=Prominent sour taste
Astringency	The sensation associated with drying of the mouth	0=None ; 100=Prominent dry mouthfeel
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 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 (first three chews)	0= None ; 100=Very juicy
Mealiness	Degree to which the flesh breaks down to very fine dry particles	0= None ; 100=Prominent mealiness
Grittiness	Presence of small hard particles in the flesh experienced between front teeth	0= None ; 100=Prominent grittiness

Table 2 Effect of harvest time (H 1 is commercial timing and H 2 was harvested one month later) and ripening period (H 1 was stored for 4 months at -0.5 ℃ and allowed to ripen for 7 days before testing whereas H 2 was stored for 3 months and taken from cold storage the day before testing) on instrumental firmness, dry matter concentration (%), titratable acidity (TA,), total soluble solids (TSS) and TSS: TA ratio for three pear cultivars harvested at Glen Fruin farm, Elgin, South Africa, in 2013.

Treatment	Harvest	Firmness (kg)	DMC (%)	TSS (˚Brix)	TA (% malic acid)	TSS:TA
Forelle	1	2.69 [b]	21 [NS]	16.62 [a]	0.17 [b]	105.63 [NS]
	2	5.10 [a]	18	15.04 [b]	0.23 [a]	65.50
P-value [z]		*<0.0001*	*0.4986*	*0.0282*	*0.0337*	*0.0554*
Packham's Triumph	1	1.14 [b]	16 [NS]	14.06 [b]	0.13 [b]	120.26 [NS]
	2	5.45 [a]	20	15.98 [a]	0.20 [a]	81.44
P-value [z]		*<0.0001*	*0.1803*	*0.0270*	*0.0234*	*0.0601*
Abate Fetel	1	2.28 [b]	16 [NS]	13.42 [NS]	0.09 [a]	150.67 [b]
	2	3.96 [a]	17	13.90	0.06 [b]	224.14 [a]
P-value [z]		*0.0001*	*0.7171*	*0.4029*	*0.0269*	*0.0020*

[Z] Means with different letters differ significantly at P≤0.05 in each column

[NS] Not significant

Table 3 Effect of harvest time (H 1 is commercial timing and H 2 was harvested one month later) and ripening period (H 1 was stored for 4 months at -0.5 °C and was allowed to ripen for 7 days before testing whereas H 2 was stored for 3 months was taken from cold storage the day before testing) on the sensory characteristics of three pear cultivars harvested at Glen Fruin farm, Elgin, South Africa. Sensory attributes were scored on a 100-mm unstructured line scale ranging from 0 to 100 according to the perceived strength of the attributes during descriptive sensory analysis in 2013.

Treatment	Harvest	Pear flavour	Hardness	Sweetness	Sourness	Astringency with peel	Astringency without peel	Grittiness	Juiciness	Melt character
Forelle	1	61 ^{NS}	22 ^{b}	54 ^{NS}	21 ^{a}	17 ^{a}	18 ^{a}	19 ^{a}	43 ^{b}	33 ^{a}
	2	56	59 ^{a}	61	16 ^{b}	5 ^{b}	3 ^{b}	15 ^{b}	52 ^{a}	6 ^{b}
P-value ^{z}		*0.0585*	*<0.0001*	*0.0912*	*0.0103*	*0.0010*	*0.0001*	*0.0051*	*0.0197*	*<0.0001*
Packham's T.	1	77 ^{a}	12 ^{b}	71 ^{a}	18 ^{b}	2 ^{b}	1 ^{b}	14 ^{NS}	74 ^{a}	75 ^{a}
	2	51 ^{b}	59 ^{a}	53 ^{b}	21 ^{a}	10 ^{a}	6 ^{a}	13	59 ^{b}	5 ^{b}
P-value ^{z}		*<0.0001*	*<0.0001*	*<0.0001*	*0.0480*	*0.0035*	*0.0049*	*0.1830*	*<0.0001*	*<0.0001*
Abate Fetel	1	61 ^{a}	32 ^{b}	56 ^{NS}	12 ^{NS}	3 ^{NS}	1 ^{NS}	19 ^{a}	57 ^{NS}	39 ^{a}
	2	49 ^{b}	57 ^{a}	54	11	2	2	16 ^{b}	58	6 ^{b}
P-value ^{z}		*<0.0001*	*<0.0001*	*0.3114*	*0.3255*	*0.2492*	*0.570*	*0.0074*	*0.7526*	*<0.0001*

^{NS} Not significant

^{Z} Means with different letters differ significantly at P≤0.05 in each column

Table 4 Effect of harvest time (H 1 is commercial timing and H 2 was harvested one month later) and storage plus ripening period (H 1 was stored for 4 months at -0.5 ℃ and allowed to ripen for 7 days before testing whereas H 2 was stored for 3 months and taken from cold storage the day before testing) on the mean eating quality and appearance liking of Stellenbosch consumers of all ethnicities, genders and age groups, for three pear cultivars harvested at Glen Fruin farm, Elgin, South Africa, in 2013.

Treatment	**Harvest**	**Liking of eating quality**	**Liking of appearance**
Forelle	1	5.6 [b]	7.4 [a]
	2	6.3 [a]	6.8 [b]
***P-value*[z]**		*0.0111*	*0.0001*
Packham's Triumph	1	6.9 [a]	7.2 [a]
	2	5.6 [b]	6.2 [b]
***P-value*[z]**		*0.0001*	*0.0001*
Abate Fetel	1	6.4 [NS]	4.8 [b]
	2	6.2	6.0 [a]
***P-value*[z]**		*0.4425*	*0.0001*

[y] Liking was scored on a 9-point hedonic scale where 1 and 9 indicate extreme dislike and liking, respectively.

[Z] Means with different letters differ significantly at P≤0.05 in each column

[NS] Not significant

Table 5 Effect of harvest time (H1 is commercial timing and H2 was harvested one month later) and storage plus ripening period (H 1 was stored for 4 months at -0.5 ℃ and allowed to ripen for 7 days before testing whereas H 2 was stored for 3 months and taken from cold storage the day before testing) on the preference for eating quality and appearance scores of three ethnic groups of Stellenbosch consumers for three pear cultivars harvested at Glen Fruin farm, Elgin, South Africa, in 2013.

Treatment	**Harvest**	**Ethnicity**	**Liking of eating quality**	**Liking of appearance**
Forelle	1	Black	5.0 [NS]	7.0 [NS]
		White	5.9	7.8
		Coloured	5.9	7.6
	2	Black	6.7	6.9
		White	7.0	7.0
		Coloured	6.7	6.7
***P*-value:**				
Harvest (H)			*0.0111*	*0.0001*
Ethnicity (E)			*0.8039*	*0.4125*
H x E			*0.0637*	*0.1104*
Packham's Triumph	1	Black	7.2 [NS]	7.1 [a]
		White	6.5	7.1 [a]
		Coloured	7.2	7.4 [a]
	2	Black	5.5	7.2 [a]
		White	5.7	5.7 [b]
		Coloured	5.6	5.8 [b]
***P*-value:**				
Harvest			*0.0001*	*0.0001*
Ethnicity			*0.6415*	*0.0421*
H x E			*0.3130*	*0.0001*
Abate Fetel	1	Black	6.2 [a]	4.8 [c]
		White	6.2 [a]	4.7 [c]
		Coloured	6.8 [a]	4.9 [bc]
	2	Black	6.8 [a]	5.7 [ab]
		White	6.2 [ab]	6.5 [a]
		Coloured	5.7 [b]	5.8 [a]
***P*-value[z]:**				
Harvest			*0.4425*	*0.0001*
Ethnicity			*0.7085*	*0.6703*
H x E			*0.0134*	*0.0147*

[y] Liking was scored on a 9-point hedonic scale where 1 and 9 indicate extreme dislike and liking, respectively.
[Z] Means with different letters differ significantly at P≤0.05 in each column
[NS] Not significant

Table 6 Socio-demographics, fruit consumption habits and perceived preference for pear eating quality attributes for two residual groups of consumers from Stellenbosch, South Africa, in 2013.

	Group 1	Group 2	*P-value*[z]
Age mean (years)	26.7 [NS]	31	*0.0812*
Fruit consumption (per week)	1.7 [NS]	1.6	*0.3013*
Pear consumption (per week during season)	2.9 [a z]	2.3 [b]	*0.0023*
Female %	76 [NS]	62	*0.1043*
Male %	24 [NS]	38	*0.1043*
Black %	17 [NS]	15	*0.6475*
Coloured %	38 [NS]	46	*0.6475*
White %	46 [NS]	40	*0.6475*
Texture hard [y]	5.0 [NS]	4.3	*0.0956*
Texture soft [y]	4.8 [b]	5.7 [a]	*0.0287*
Juicy [y]	6.1 [NS]	6.8	*0.0648*
Pear flavour [y]	6.8 [NS]	6.4	*0.2656*
Sweetness [y]	6.2 [NS]	6.4	*0.6084*

[y] Liking was scored on a 9-point hedonic scale where 1 and 9 indicate extreme dislike and liking, respectively, and 5 represents neither dislike nor liking.

[Z] Means with different letters differ significantly at P≤0.05 as indicated in rows

[NS] Not significant

Table 7 Effect of harvest time (H1 is commercial timing and H2 was harvested one month later) and ripening period (H1 was stored for 4 months at -0.5 °C and allowed to ripen for 7 days at 20 °C before testing and H2 was stored for 3 months at -0.5 °C and taken from cold storage the day before testing) on the liking of eating quality and appearance for two residual groups (groupings based on similar preference patterns) of Stellenbosch consumers for three pear cultivars harvested at Glen Fruin farm, Elgin, South Africa, in 2013.

Treatment	Harvest	Group	Liking of eating quality	Liking of appearance
Forelle	1	1	3.4 [c]	8.1 [a]
		2	6.9 [a]	6.9 [b]
	2	1	7.3 [a]	6.9 [b]
		2	5.7 [b]	6.7 [b]
P-value*[z]*:				
Harvest			*0.0001*	*0.0001*
Group			*0.0001*	*0.0015*
Harvest x Group			*0.0001*	*0.0001*
Packham's Triumph	1	1	5.6 [b]	7.2 [a]
		2	7.4 [a]	7.3 [a]
	2	1	5.8 [b]	5.5 [c]
		2	5.5 [b]	6.6 [b]
P-value*[z]*:				
Harvest			*0.0026*	*0.0001*
Group			*0.0119*	*0.0001*
Harvest x Group			*0.0001*	*0.0002*
Abate Fetel	1	1	5.8 [b]	3.7 [d]
		2	6.7 [a]	6.5 [b]
	2	1	7.0 [a]	5.3 [c]
		2	5.6 [b]	7.1 [a]
P-value*[z]*:				
Harvest			*0.8943*	*0.0001*
Group			*0.4279*	*0.0001*
Harvest x Group			*0.0001*	*0.0003*

[y] Liking was scored on a 9-point hedonic scale where 1 and 9 indicate extreme dislike and liking, respectively, and 5 represents neither dislike nor liking.

[Z] Means with different letters differ significantly at P≤0.05 in the column

[NS] Not significant

Table 8. Pearson's correlation matrix for consumer preference of eating quality for three pear cultivars at two harvest dates and ripening periods (H 1 was stored for 4 months at -0.5 ℃ and allowed to ripen for 7 days before testing whereas H 2 was stored for 3 months and taken from cold storage the day before testing) with sensory attributes analysed by the trained panel and instrumental measurements included fruit firmness (kg), total soluble solids (TSS), titratable acidity (TA), TSS:TA and dry matter content (DMC %). Sensory attributes included pear flavour, sweet taste, sour taste, astringency with peel, hardness, melt character, juiciness and grittiness. Values in bold correlated significantly (P≤0.05).

Variables	Firmness (N)	DMC (%)	TSS (˚Brix)	TA	TSS:TA	Pear flavour	Hardness	Sweetness	Sourness	Astringency	Grittiness	Juiciness	Melt character
Firmness (N)	**1**	0.460	0.395	0.539	-0.288	**-0.842**	**0.939**	-0.543	0.101	0.172	-0.412	-0.378	**-0.934**
DMC (%)	0.460	**1**	**0.976**	0.615	-0.478	-0.380	0.177	-0.552	0.750	**0.944**	0.038	-0.686	-0.430
TSS (˚Brix)	0.395	**0.976**	**1**	0.720	-0.614	-0.214	0.079	-0.360	**0.856**	**0.930**	-0.061	-0.589	-0.304
TA	0.539	0.615	0.720	**1**	**-0.945**	-0.084	0.253	0.021	0.708	0.514	-0.354	-0.334	-0.296
TSS:TA	-0.288	-0.478	-0.614	**-0.945**	**1**	-0.187	0.005	-0.199	-0.746	-0.459	0.302	0.173	0.011
Pear flavour	**-0.842**	-0.380	-0.214	-0.084	-0.187	**1**	**-0.892**	**0.843**	0.219	-0.152	0.024	0.523	**0.967**
Hardness	**0.939**	0.177	0.079	0.253	0.005	**-0.892**	**1**	-0.530	-0.234	-0.120	-0.370	-0.248	**-0.939**
Sweetness	-0.543	-0.552	-0.360	0.021	-0.199	**0.843**	-0.530	**1**	0.057	-0.474	-0.366	0.707	0.737
Sourness	0.101	0.750	**0.856**	0.708	-0.746	0.219	-0.234	0.057	**1**	0.757	-0.293	-0.144	0.120
Astringency	0.172	**0.944**	**0.930**	0.514	-0.459	-0.152	-0.120	-0.474	0.757	**1**	0.279	-0.706	-0.177
Grittiness	-0.412	0.038	-0.061	-0.354	0.302	0.024	-0.370	-0.366	-0.293	0.279	**1**	-0.600	0.128
Juiciness	-0.378	-0.686	-0.589	-0.334	0.173	0.523	-0.248	0.707	-0.144	-0.706	-0.600	**1**	0.548
Melt character	**-0.934**	-0.430	-0.304	-0.296	0.011	**0.967**	**-0.939**	0.737	0.120	-0.177	0.128	0.548	**1**

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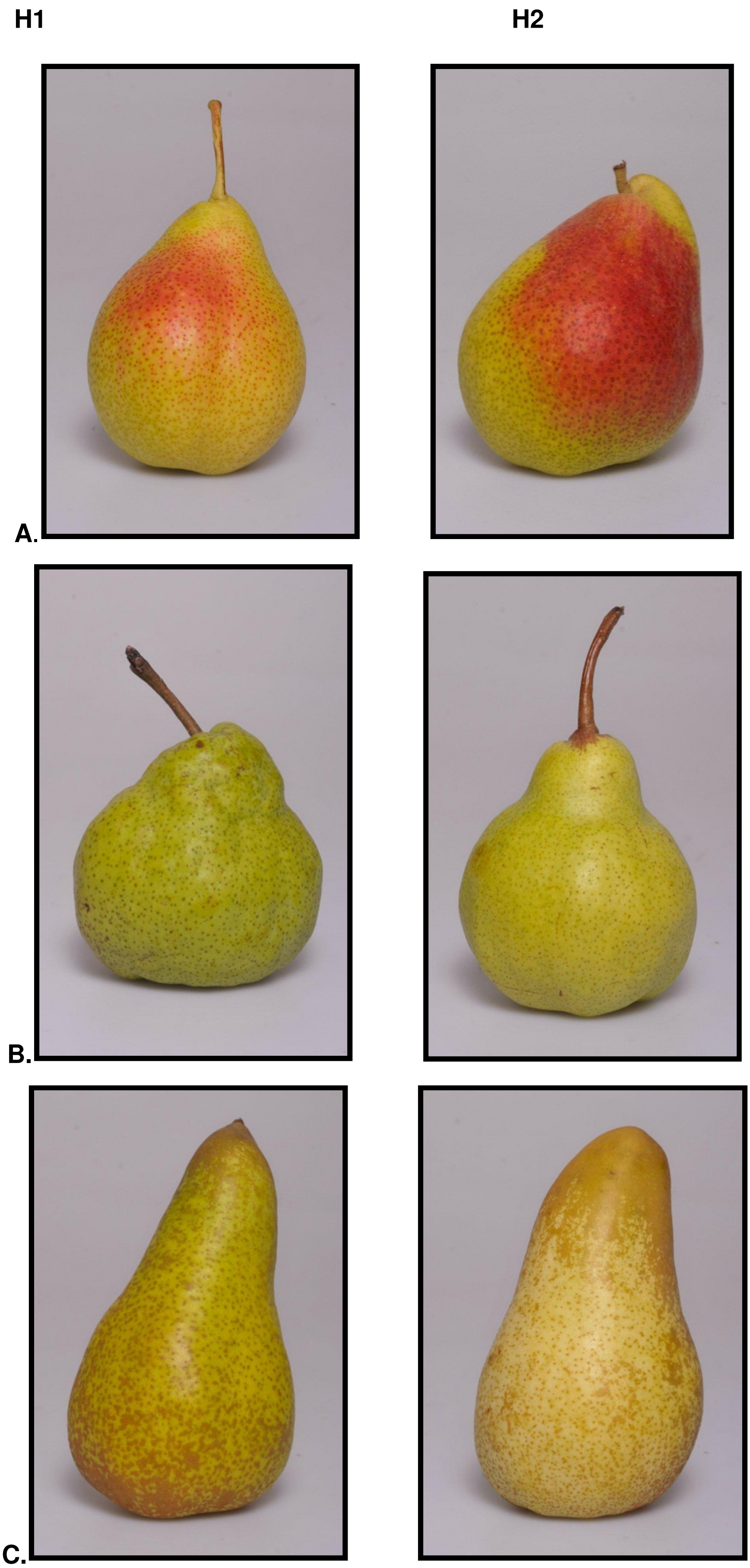

Figure 1. Images of first and second harvest pears of ‘Forelle’ (A), ‘Packham’s Triumph’ (B) and ‘Abate Fetel’ (C).

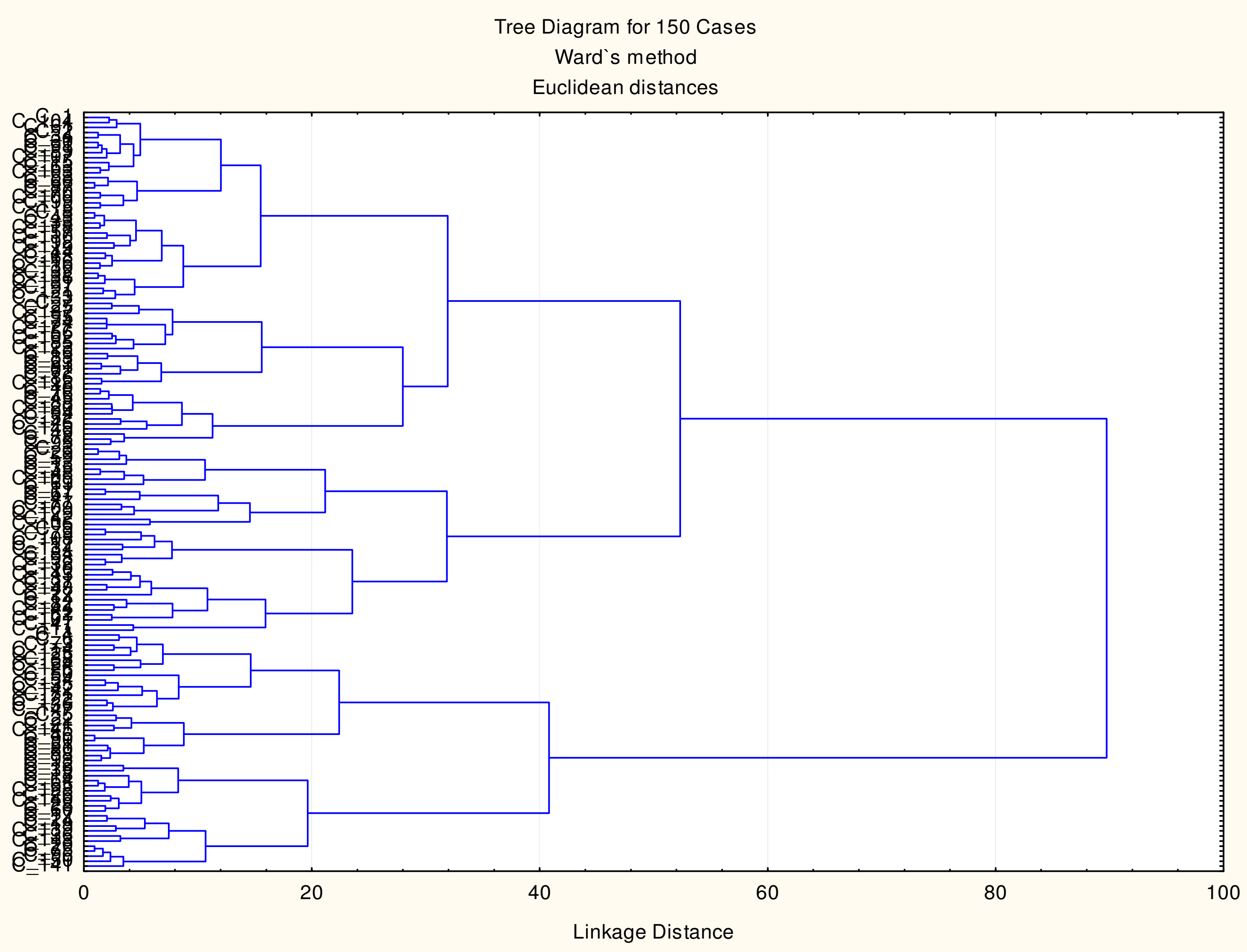

Figure 2. Tree diagram illustrating segmentation of consumer preference for eating quality for 150 consumers using Ward's cluster analysis.

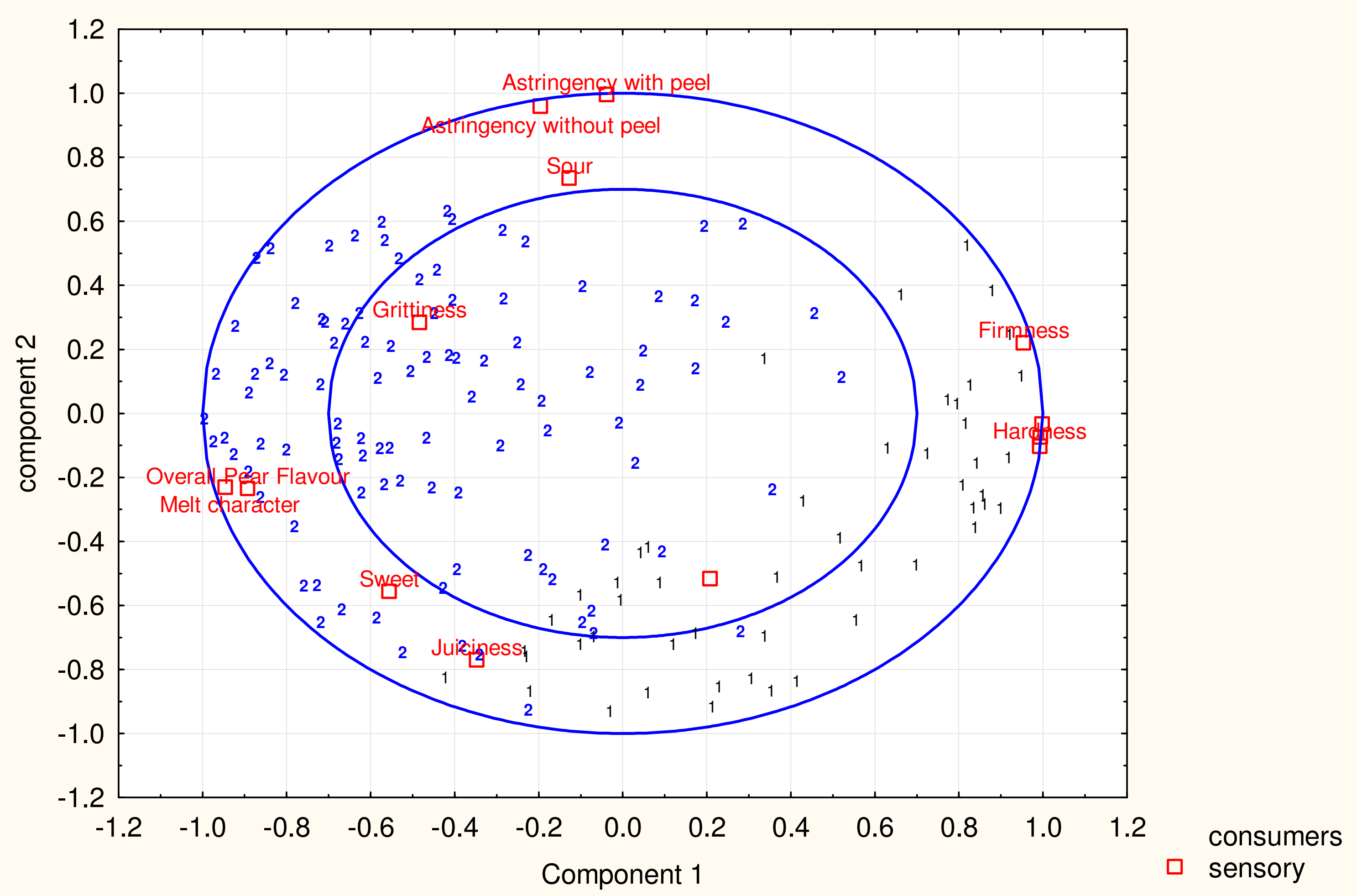

Figure 3. PCA correlation plot of the preferences of two consumer groups' (indicated as 1 and 2) for eating quality correlated to sensory attributes of pears (in red) along with the instrumental measurement of firmness (also in red).

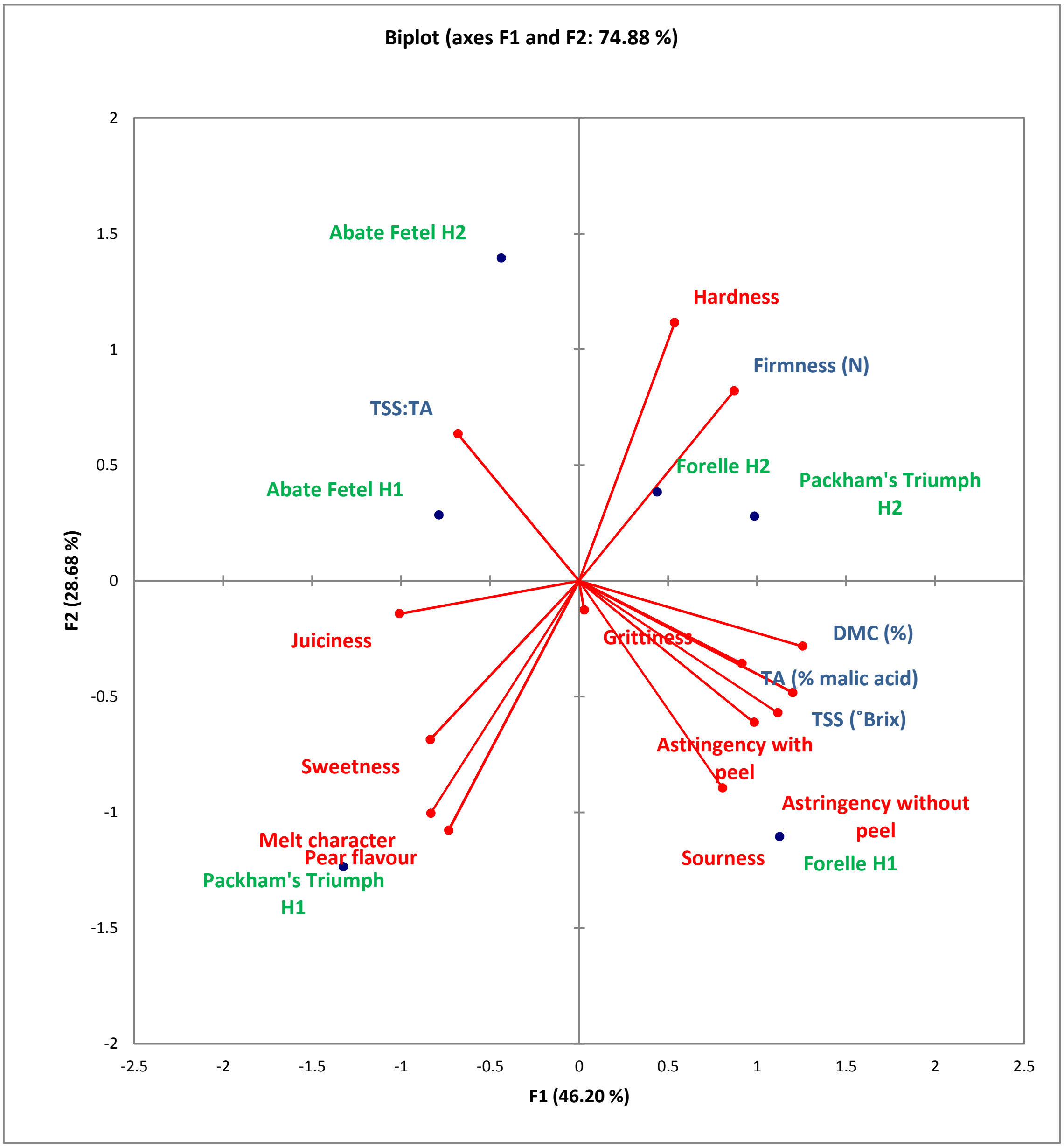

Figure 4. PCA bi-plot indicating associations between the physiochemical measurements (in red) and sensory attributes (in blue) and how the different cultivars (in green) at both harvests (H1/H2) relate to these.

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GENERAL DISCUSSION AND CONCLUSIONS

South Africa is a developing country with a multicultural society and diverse socio-economic profile (Viljoen and Gericke, 2001). Due to differences in traditional food habits and availability of regional flavour sources, the degree of liking of food differs across regions (Pangborn *et al*., 1988). White and coloured consumers' eating patterns are generally described as Western, but are perceived to differ from those of black consumers (Viljoen and Gericke, 2001). Van der Merwe (2013) indeed found differences in the preferences of white, coloured and black consumers in the Stellenbosch region of the Western Cape province of South Africa for apple appearance and taste. Black and coloured consumers generally preferred sweeter fruit than white consumers. Although ethnicity is one of the key determinants of food choice (Prescott and Bell, 1995), its effect on food preference (Pangborn *et al.*, 1988), and thus ultimately the marketing thereof, is poorly understood.

With this is mind, we set out to determine the differences, if any, in preference for pear eating quality and appearance amongst ethnic groups in the Western Cape region of South Africa. During the first study **(Paper 1)**, a trained panel of judges were used to analyse the sensory characteristics of 10 pear genotypes and then 421 consumers from different age, gender and ethnic groups did a taste test and filled in questionnaires recording their preferences for pear eating quality and appearance. Instrumental measurements were also taken of each cultivar and correlations were determined between variables. The objective was to determine the preferred appearance and the general drivers of liking for pear eating quality. Consumer preference ratings are of a hedonic nature as they do not give any descriptions, only which product they prefer. Therefore, it was 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 data indicate that the majority of consumers of all three ethnic groups, genders and ages in the Western Cape, show a preference for pears with a distinct pear flavour, a sweet taste but also containing a fair amount of acid and soft, juicy flesh with melt character. There are also indications that a yellow or pale green peel

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colour and a typical pear shape (elongate-concave) were preferred, but we assessed shape and colour together and a different experimental design would be required to separate preference for shape and colour. Our data seem to support the findings of previous research done by Manning (2009) on consumer preference of pears in the Western Cape, South Africa. There were no large differences in preference for the three ethnic groups in our study and this is similar to the results from a previous pear study done by Jaeger *et al.* (2003) where there was no segmentation between New Zealand natives and recent immigrants from Taiwan who had lived in NZ less than 1 year. In the latter study consumer groupings with similar preferences were identified, but ethnicity was not significantly different between groups.

However, in our study two clusters of consumers were identified that have similar preferences. Group 1 consisted of 231 (55 %) consumers while group 2 had 190 (45 %). For both eating quality and appearance the two consumer clusters identified showed no obvious differences in composition in terms of gender, ethnicity or age. Overall, group 1 indicated a liking for a wider range of cultivars while group 2 has a small selection of cultivars that they really like for appearance and eating quality. Interestingly group 2 used the upper part of the hedonic scale for the small selection of cultivars that they really liked. It seemed that group 2 are more familiar with pears in general and show a definite preference for the cultivars they are familiar with and like. In contrast, group 1 in all instances used the lower part of the hedonic scale and it seemed that their like and dislikes are not as clearly defined, which could be exploited through clever marketing.

In terms of drivers of liking, Elkins *et al.* (2008) in similar research done in the United States, found that sweetness and melting texture were the main reasons for consumers liking a European pear cultivar, while appearance, i.e., peel colour, was the least important factor. They also found that a gritty texture and lack of flavour were key reasons for disliking a cultivar. In our study and in the research done by Manning (2009), astringency was found to have a very negative effect on consumer preference. Jaeger *et al.* (2003) found that consumers in New Zealand preferred European over Asian or hybrid genotype pears and, further, indicated a preference for ripe over unripe samples. The latter finding agreed with questionnaire responses from the same consumers describing their “ideal” pears as sweet and juicy. These two attributes, sweet and juicy, were the distinguishing differences between ripe and unripe samples and correlates well with our findings. According to Elkins and Mitcham (2007), studies show that consumers prefer ripened pears by a margin of 3 to 1 over unripe pears and suggest that pears should be ripened at or near the retail market as partially ripe fruit are much more susceptible to bruising injury during transportation. This study agrees with these findings. Mealiness, where pear flesh is characterised by low extractable juice content, is the key internal quality disorder associated with the sensory quality of 'Forelle' pears in South Africa (Crouch, 2011; Carmichael, 2011; Martin, 2002). Previous studies also showed that mealiness is the main reason for consumer dislike in apples (Jaeger *et al*., 1998; Andani *et al.,* 2001) and pears (Manning, 2009). In our study, however, no mealiness was detected. It was interesting to note that the 'Bon Chretien' used for this trial was allowed to ripen on the tree and was then kept in cold storage for 3 months. It was the most preferred pear for its appearance and came second for eating quality. This suggested that allowing pears to ripen on the tree could make a huge difference in Western Cape Province consumer satisfaction, leading to further research to investigate the effect of harvest time and ripeness on consumer preference for pear eating quality and appearance, especially yellowing **(Paper 2)**. Three pear cultivars, viz. Packham's Triumph, Abate Fetel and Forelle were harvested on two dates one month apart. The first harvest (H1) was during the commercial harvest date and the second harvest followed a month later.

Physiochemical measurements were taken and sensory attributes assessed for both harvest dates. Then 150 consumers of different ethnic groups from the Western Cape Province, South Africa, recorded their preferences for the taste and appearance of the pears of both harvest dates on a hedonic scale. Principal component analysis (PCA) was performed to project instrumental measurements onto the sensory dimensions to investigate the eating quality parameters that associated with each of the treatments. Two main groups of consumers were identified; group 1 (33% of the total consumer group) showed a preference for the characteristics of crispness, hardness and firmness, while the larger number of consumers of group 2 (67%) indicated a positive correlation with melt character, juiciness, overall pear flavour and sweet taste. This is similar to results obtained by Elkins and Mitcham (2007), indicating that consumers prefer ripened pears by a margin of 3 to 1 over unripe pears. In our study, however, the ratio is 2 to 1 in favour of ripe pears. The latter characteristics were the most prominent in first harvest 'Packham's Triumph' pears that were ripened for seven days. It is evident from this research that harvest maturity and ripeness have a significant effect on the sensory and physicochemical attributes of pears and thus ultimately consumer preference. The firmness and sensory hardness of harvest one (H1) fruit were significantly lower, and melt character significantly higher than harvest two (H2) fruit for all three cultivars while the dry matter concentration (DMC) levels were unchanged between harvests. Other differences were not consistent between cultivars and may be the reason for differences in consumer preference for H1 or H2 fruit, indicating that preference for pear eating quality can be cultivar specific.

This study simulated the FEMA programme, where 'Forelle' pears are allowed to tree-ripen to compensate for their inability to respond to ethylene as a ripening agent after the application of 1-methylcyclopropene (1-MCP; SmartFresh™ AgroFresh Inc., Philadelphia, PA, USA) at harvest (Crouch and Bergman, 2013). The latter are then marketed as "crisp and sweet" compared to the traditional soft and melty texture that ripe European pears attain. Our results indicated that 'Forelle' is suitable for this treatment, as Western Cape Province consumer preference was aligned with the eating quality characteristics of later harvested, i.e. more mature, but less shelf ripe, 'Forelle' pears. Marketing 'Forelle' pears as "crisp and sweet" circumvents the negative effects of mealiness and astringency, which are the major negative eating characteristics of this cultivar as well as the mandatory 12 weeks cold storage period needed to curb the high incidence of mealiness (Crouch and Bergman, 2013). Western Cape Province consumers generally did not like the eating quality characteristics of later harvested, but less shelf-ripe 'Packham's Triumph' pears. Hence, 'Packham's Triumph' does not seem suitable for 1-MCP treatment as it would inhibit the eating quality characteristics that consumers favour for this cultivar. However, ripening 'Packham's Triumph' to a ready-to-eat stage and then treating it with 1-MCP on the local market to stop further ripening and postharvest quality deterioration could offer a solution (Moya-León *et al.* 2006). Dynamic Controlled Atmosphere (DCA) could be an appealing option for 'Packham's Triumph' as it has been shown to inhibit superficial scald on these pears for up to eight months in storage.

It also maintains the post-harvest quality of the fruit through increased firmness retention and better peel colour retention at shelf life conditions (Prange *et al*. 2011). While consumers indicated no preference between early harvested and shelf-ripe compared to later harvested but less shelf ripe 'Abate Fetel' pears, research by Zerbini *et al*. (2005) indicated possible benefits for treating this cultivar with 1-MCP as it allowed fruit to retain flavour and good texture during cold storage while lowering the incidence of superficial scald. A possible problem with the use of 1-MCP for this cultivar is its slowing of the ground colour development, as this research shows that consumers prefer the appearance of ripe pears. However, allowing some level of yellowing on the tree may address this problem and also ensure that fruit meet background colour standards.

Conclusions and recommendations

Only 2% of pears are currently exported into Africa and low levels (15%) are consumed locally (HORTGRO, 2015). Van der Merwe (2013), in a similar study on apples, found that coloured and black consumers' preference on average manifested in high liking scores for cultivars with high sweetness and low sour taste. As black consumers dislike in sourness and acidity is considerably lower in pears than in apples, so much so that it may be undetectable as a component of taste (Jackson, 2003), it could explain why there are no clear differences between ethnic groups for preference for pear eating quality. Black consumers scored pears of suitable eating quality quite high; this might indicate a growth opportunity for the industry. It is evident, however, that the consistency of pear eating quality as it relates to harvest maturity and level of ripening, could have a significant effect on consumer satisfaction when eating pears.

A considerable market (about a third of consumers) seemed to exist for firm, juicy pears such as tree-ripened European pears treated with 1-MCP or Asian pears. However, South African consumers are not familiar with the appearance of Asian pears and considerable market development will be needed. Our results also suggest that not all European pears may be suitable for firm and juicy consumption. To further assess the effect of harvest maturity on pear eating quality characteristics and consumer preference, future studies could assess pears harvested at different

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maturities, but with standardised storage and ripening duration. To better asses preference for appearance, future studies should include replicates of photos and make sure background colour is visible in images of bi-coloured cultivars. Many studies have investigated consumer preference of apples while comparatively few have done so for pears. Further preference studies would allow for the mining of more information that could prove very useful to the pear industry in terms of cultivar selection, farming practices and market identification.

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