PREFERENCE OF SOUTH AFRICAN CONSUMERS FOR THE EATING QUALITY AND APPEARANCE OF APPLES

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Dissertation presented for the degree of Doctor of Philosophy (Horticultural Science) at the University of Stellenbosch

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December 2016

DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signature: Date:

SUMMARY

Considering that 27% of South Africa's apple crop is sold locally, we aimed to determine the attributes that drive South African consumers' apple eating quality and appearance preferences. Since a previous study focused on consumers from Stellenbosch in the Western Cape Province, we focused on consumers from Pretoria in Gauteng Province as well as consumers from Durban in Kwa-Zulu Natal Province of varying age (18-25, 26+), gender and socio-economic backgrounds. Consumer preference analysis for apple eating quality and appearance, and descriptive sensory analysis were performed on nine commercial apple cultivars selected to obtain large variations in the various eating quality attributes and not compared to each other *per se*.

On average, young (18-25) white and Indian consumers were found to prefer firm, sour cultivars and green peel colour but disliked mealiness and sponginess. Black, older and male consumers generally preferred sweetness, but disliked sourness. Appearance preferences were generally consistent with eating quality preferences. Consumers' actual liking scores generally also associated with their conceptual preferences, except in the case of unfamiliar cultivars. Ward's statistical clustering indicated three consumer clusters with distinct preferences for both eating quality and appearance. Eating quality clusters 1 and 2 (E1 and E2) liked sweet taste, tolerated mealiness but disliked sour taste. E1 also associated with sponginess, but E2 did not. E3 liked sensory attributes relating to firmness, tolerated sour taste but disliked mealiness and sponginess. E1 and E2 were overrepresented with black and older (26+) consumers while young white and young Indian consumers were overrepresented in E3. Compared to international studies, the sweet-liking consumer group seemed to be larger in South Africa due to the general sweet taste preference of black consumers. However, since black consumers make up the majority of the total South African population, firm and sour apples should also be marketed to these consumers. Appearance cluster 1 (A1) preferred red and green/yellow apples, A2 preferred red and green apples while A3 preferred green apples.

Ripening-related changes in eating quality attributes and appearance with increasing shelf-life duration impact significantly on consumer preference. We studied the preferences of different ethnic and age groups for 'Golden Delicious' and 'Topred' apples of varying ripeness levels. Coloured consumers, but older coloured consumers in particular, showed little to no difference in preference for the eating quality and appearance of riper, softer apples compared to less ripe, firmer apples. White and black consumers showed a decrease in liking with

increasing shelf life duration. The shelf-life of apples could possibly be extended in outlets favoured by coloured consumers. Black consumers do not seem to have a high preference for riper apples as suggested by the previous Western Cape study. Rather, their high preference for sweetness results in some tolerance of riper apples. Peel colour did not provide a good indication of eating quality characteristics. In ‘Topred’, the red overcolour masked yellowing while in ‘Golden Delicious’, eating quality attributes changed much less than peel colour.

OPSOMMING

Gegewe dat 27% van Suid-Afrikaanse appels plaaslik verkoop word, het ons die eienskappe bepaal wat plaaslike verbruikers se eetkwaliteit- en appelvoorkomsvoorkeure dryf. 'n Vorige verbruikersvoorkeurstudie is op Stellenbosch in die Wes-Kaap Provinsie onderneem. Gevolglik het ons gefokus op verbruikers van Pretoria in Gauteng Provinsie asook verbruikers van Durban in Kwa-Zulu Natal Provinsie. Die verbruikers was van verskillende ouderdomme (18-25, 26+), geslag en sosio-ekonomiese agtergronde. Analise van verbruikersvoorkeure vir appel eetkwaliteit en – voorkoms asook beskrywende sensoriese analise is uitgevoer op nege kommersiële kultivars wat geselekteer is om groot variasie in eetkwaliteiteienskappe te verkry. Die kultivars is nie opsigself met mekaar vergelyk nie.

Jong (18-25) wit en Indiër verbruikers het oor die algemeen ferm, suur kultivars en groenskilkleur verkies, maar het 'n afkeur gehad in melerigheid en sponserigheid. Swart, ouer en manlike verbruikers het oor die algemeen soetheid verkies en 'n afkeur gehad in suurheid. Voorkomsvoorkeure was oor die algemeen in ooreenstemming met eetkwaliteitvoorkeure. Verbruikers se werklike voorkeure was oor die algemeen ook in ooreenstemming met hul konseptuele voorkeure, buiten in die geval van onbekende kultivars. Met gebruik van Ward se statistiese groepering kon ons op grond van voorkeure onderskei tussen drie verbruikersgroepe vir beide eetkwaliteit en voorkoms. Eetkwaliteitsgroepe 1 en 2 (E1 en E2) het soet smaak verkies, melerigheid getolereer, maar 'n afkeer gehad in suur smaak. E1 het ook met sponserigheid geassosieer. E3 het sensoriese eienskappe wat verband hou met fermheid verkies, suur smaak getolereer, maar 'n afkeer gehad in melerigheid en sponserigheid. Swart en ouer (26+) verbruikers was oorverteenwoordig in E1 en E2 terwyl jong wit en jong Indiër verbruikers oorverteenwoordig was in E3. Vergeleke met internasionale studies, lyk dit of Suid-Afrika 'n groter soet-voorkeur verbruikersgroep het, waarskynlik vanweë die algemene soetsmaakvoorkeur van swart verbruikers. Tog moet ferm en suur appels steeds aan swart verbruikers bemark word, gegewe dat hulle die oorgrote meerderheid uitmaak van die totale Suid-Afrikaanse populasie. Voorkoms groep 1 (V1) het rooi en groen/geel appels verkies, V2 het rooi en groen appels verkies en V3 het groen appels verkies.

Rypheid-geassosieerde veranderinge in eetkwaliteiteienskappe en voorkoms het 'n groot impak op verbruikersvoorkeur. Ons het die voorkeure van verskillende etniese en ouderdomsgroepe vir 'Golden Delicious' en 'Topred' appels van verskillende rypheidsvlakke bestudeer. Bruin verbruikers, veral ouer bruin verbruikers, het eweveel gehou van die

eetkwaliteit en voorkoms van ryper, sagter appels en minder ryp, fermer appels. Wit en swart verbruikers het ’n afname in voorkeur getoon met ’n toename in rakleeftyd. Die rakleeftyd van appels sou moontlik verleng kon word in afsetpunte wat merendeel bruin verbruikers bedien. Anders as wat deur ’n vorige Wes-Kaap studie gesuggereer is, het swart verbruikers nie ’n hoë voorkeur vir ryper appels gehad nie. Dis eerder hul hoë voorkeur vir soetheid wat lei tot ’n mate van toleransie vir ryper appels. Skilkleur het nie ’n goeie aanduiding van eetkwaliteiteienskappe gegee nie. In ‘Topred’ het die oppervlakkige rooi kleur vergeling gemaskeer terwyl in ‘Golden Delicious’ eetkwaliteitseienskappe aansienlik minder as skilkleur verander het.

ACKNOWLEDGEMENTS

I would like to express my profound gratitude to the following people and institutions for making this research possible:

My promoter Prof W.J. Steyn for his mentorship, encouragement, guidance, patience and priceless contribution throughout the course of my studies. Your academic skill and commitment is exceptional.

My co-promoter Ms M. Muller for her patience and enthusiasm in training and assisting me in the sensory and consumer science aspects of this research. Your invaluable contribution towards this research, as well as your kind words of encouragement and motherly care is very much appreciated.

My co-promoter Prof K.I. Theron for all her assistance in the course of my studies and her keen interest in my total well-being. Your attention to the fine details of every sentence in the entire dissertation is treasured.

My co-promoter Prof Tormod Næs for his assistance in solving the difficult statistical questions in the course of my studies.

Mrs M. van der Rijst of the ARC Biometry Unit for all the hours of data analysis. Your door was always open to me and you assisted me without reservation. Your kindness meant a lot to me.

Mrs E.D. Moelich for your guidance and assistance with my trained panel sessions.

The sensory panel, for your dedication, kindness and interest in the success of this research.

Mr John Achilles, as well as colleagues and friends at the sensory research laboratory at the Department of Food Science for assisting with all my laboratory and sample preparation.

Mr G. Lötze and the technical staff in the Department of Horticultural Science for assisting me with my physical analyses.

The staff and students of the Department of Food Science, University of Pretoria and Department Food and Nutrition: Consumer Sciences, Durban University of Technology for assisting me in every possible way with consumer recruitments and tasting sessions.

Colors Fruit, Valley Parkers Co-op Ltd, Du Toit Agri (Pty) Ltd and Kromco (Pty) Ltd for providing the apples needed for this research.

The Hope Project of Stellenbosch University for funding this research.

The Vice-Chancellor and Registrar of Kwame Nkrumah University of Science and Technology (KNUST) for granting me permission and assistance for my studies.

Colleagues, fellow students, extended family members and friends who encouraged and supported me in diverse ways.

Thank you very much Kwesi, Maame Konadu and Kofi for your labour of love, firm support and priceless sacrifice. I appreciate each one of you very much.

Above all, thank you dear Lord for granting me the needed grace to go through this journey. Your faithfulness never failed and was renewed every morning.

DEDICATION

This thesis is entirely dedicated to my dear husband and our wonderful children, for the priceless sacrifice they made, to enable me embark on this journey.

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

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GENERAL INTRODUCTION

The apple (*Malus x domestica* Borkh.) is one of the world's leading fruit crops with about 81 million tonnes produced worldwide in 2014 at a value of 34 billion US dollars (FAOSTAT, 2014). South Africa ranks fifteenth at 811,523 tonnes or about 1.0% of global apple production in 2014 with a value of about 342 million US dollars (FAOSTAT, 2014). South Africa's apples are cultivated on an area of 22,501 hectares (HORTGRO, 2015). Forty-two percent of the South Africa's apple crop is sold on the export market, 27% sold on the domestic market and 29% processed, while the remaining 2% is dried (HORTGRO, 2015).

Dependency on export markets is a considerable liability, considering that sales on exports markets tend to be rather unpredictable as a result of unforeseen circumstances (such as the Russian ban of European Union agricultural produce), intense competition and very stringent phytosanitary rules. By illustration, Poland, the world's fourth largest apple producer (FAOSTAT, 2014), sold a quarter of all its apples (1 million tonnes) to Russia in 2013 (Rankin, 2014) but following Russia's import ban in 2014, apple growers in Poland are on the edge of bankruptcy (Rankin, 2014). Also, South Africa had to suspend exports of citrus to the European Union because the European Union threatened a permanent ban after four shipments of citrus exported from South Africa were found to contain citrus black spot disease infected fruit (Vecchiatto, 2014). The action resulted in loss of revenue estimated at one billion South African rands (about 85 million US dollars) (Vecchiatto, 2014). South African apple exports to the United Kingdom, which used to be the largest export market for South Africa's apple with a market share of 37% in 2009, has declined to 17% in 2015 (HORTGRO, 2015).

Considering that the number of middle and high income consumers in South Africa have markedly increased since 1994 (SAARF, 2012) and that consumers in the middle to upper income brackets prefer fresh fruits over canned fruit (GAIN Report, 2012), it should be possible to increase apple sales on the local market and thereby decrease our dependence on the export market. Therefore, evaluating the intrinsic and extrinsic factors that drive the preference of local consumers for apple eating quality and appearance is important since the local consumer is increasingly seen as a potential target for apple sales.

Consumer preference for apple eating quality is driven by attributes such as sweet taste, moderate sour taste, apple flavour (characteristic of apple type), crispness, crunchiness and juiciness (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Andani *et al*., 2001; Van der Merwe, 2013; Bonany *et al*., 2014). Appearance, particularly peel colour and fruit size, are important factors that influence consumer preference for apple quality and thereby affect sales (Crassweller and Hollender, 1989; Cliff *et al.*, 2002). Consumers' perception of fruit quality, especially in relation to fruit taste, as well as their decision to buy apples, is largely influenced by fruit colour (Jaeger and MacFie, 2001; Shankar *et al.*, 2010; Steyn, 2012). A strongly acidic taste, brown flesh, bruised fruit, fruit with a large core and thick peel, as well as a mealy or mushy texture are negative apple quality attributes (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Brown and Maloney, 2006). Extrinsic factors such as price and packaging, as well as socio-demographic factors like race, age, gender and income level also impact on consumer preference for apple quality (Daillant-Spinnler *et al*., 1996; Richards, 1999; Patterson and Richards, 2000; Brown and Maloney, 2006).

Daillant-Spinnler *et al.* (1996), Jaeger *et al.* (1998), Carbonell *et al.* (2008) and Bonany *et al*. (2014) evaluated attributes that drive preference of European consumers for apple quality using preference mapping. A projection of the outcome of descriptive sensory analysis onto consumer preference dimension revealed consumer segments that differed in their preference for quality attributes. Socio-demographic characteristics of consumers (Helgesen *et al*., 1997; Thybo *et al*., 2003) and similarity in preference patterns (Daillant-Spinnler *et al.*, 1996; Carbonell *et al.*, 2008) determine consumer groups. Similar techniques were used to evaluate the attributes that drive the preference of black, coloured and white consumers of varying age groups for apple quality in the Stellenbosch area of the Western Cape Province of South Africa (Van der Merwe, 2013). Both ethnic and age differences in general apple eating quality and appearance preferences were found. In addition, although consumers from all ethnic and age groups were present in the three consumer segments that were found, the proportion of consumers from different ethnicities and ages in each segment differed. Van der Merwe (2013) suggested that these findings may have implications for the marketing and targeting of apples to South African consumers. However, further research is needed to determine whether findings also extend to other regions and ethnic groups in South Africa.

Knowledge of what the preferences of South African consumers are and how they are grouped in relation to the attributes that drive their preference patterns will not only help marketers target consumers according to their preferences, but will also lead to consumer satisfaction and therefore an increase in apple sales. In addition, the information could be useful to local breeders and cultivar developers in that it will allow them to focus on breeding and evaluating potential new cultivars with desired attributes for specific groups of consumers.

There is no published information on the intrinsic and extrinsic attributes that drive the apple quality preferences of South African consumers in other Metropolitan regions. These regions are characterised by consumers of different ethnic and socioeconomic backgrounds (Viljoen and Gericke, 2001a). The country is made up of nine provinces of which the Western Cape (11.3% of the total population), Gauteng (23.7% of total population) and Kwa-Zulu Natal (19.8% of the total population) are the regions with the highest spending power. The Western Cape province consists of 30% black, 19% white, 50% coloured and 1% Indian consumers with the Gauteng province comprising 74% black, 20% white, 4% coloured and 2% Indian consumers while the Kwa-Zulu Natal province is inhabited by 85% black, 5% white, 1% coloured and 9% Indian consumers (STATSSA, 2013). Therefore, the focus of the study was to evaluate apple quality attributes such as sweetness, crispness, juiciness and mealiness (Appendix 1), to mention but a few that drives the preference of consumers but was not to assess consumers preference of different apple cultivars *per se*.

An extensive literature review was done on the attributes that drive preferences of consumers for apple quality in relation to gender, as well as different ethnic and age groups. Insight was gained into qualitative and quantitative methods for determining apple quality, as well as, preference mapping as a tool for determining consumer preference. Knowledge was also obtained on consumer differences in relation to apple maturity.

This study was conducted as a collaboration between the Departments of Horticultural Science and Food Science at Stellenbosch University, South Africa, among consumers in the Gauteng, Kwa-Zulu Natal and Western Cape Provinces. The study constituted four separate projects depicted in Figure 1:

1) Instrumental and descriptive sensory analyses were applied to nine commercial apple cultivars to identify the drivers of liking for apple eating quality and appearance for consumers from different age (18-25, 26+) and ethnic groups (black, white and Indian) (2012).

2) Conceptual preferences were analysed for diverse components including eating quality attributes, peel colour and colouring patterns, apple cultivar, as well as purchase and consumption factors on a 9-point hedonic scale for consumers from different age (18-25, 26+) and ethnic groups (black, white and Indian) (2012).

3) Consumer segments with similar preferences for apple eating quality and appearance were identified by statistical clustering and the socio-demographic composition of the different clusters were compared (2012).

4) Apple texture thresholds at progressive maturity levels for consumers of different consumer segments and the association of ripeness level and texture with fruit appearance were assessed using descriptive sensory and instrumental analyses, as well as means of consumer liking scores (2013 & 2014).

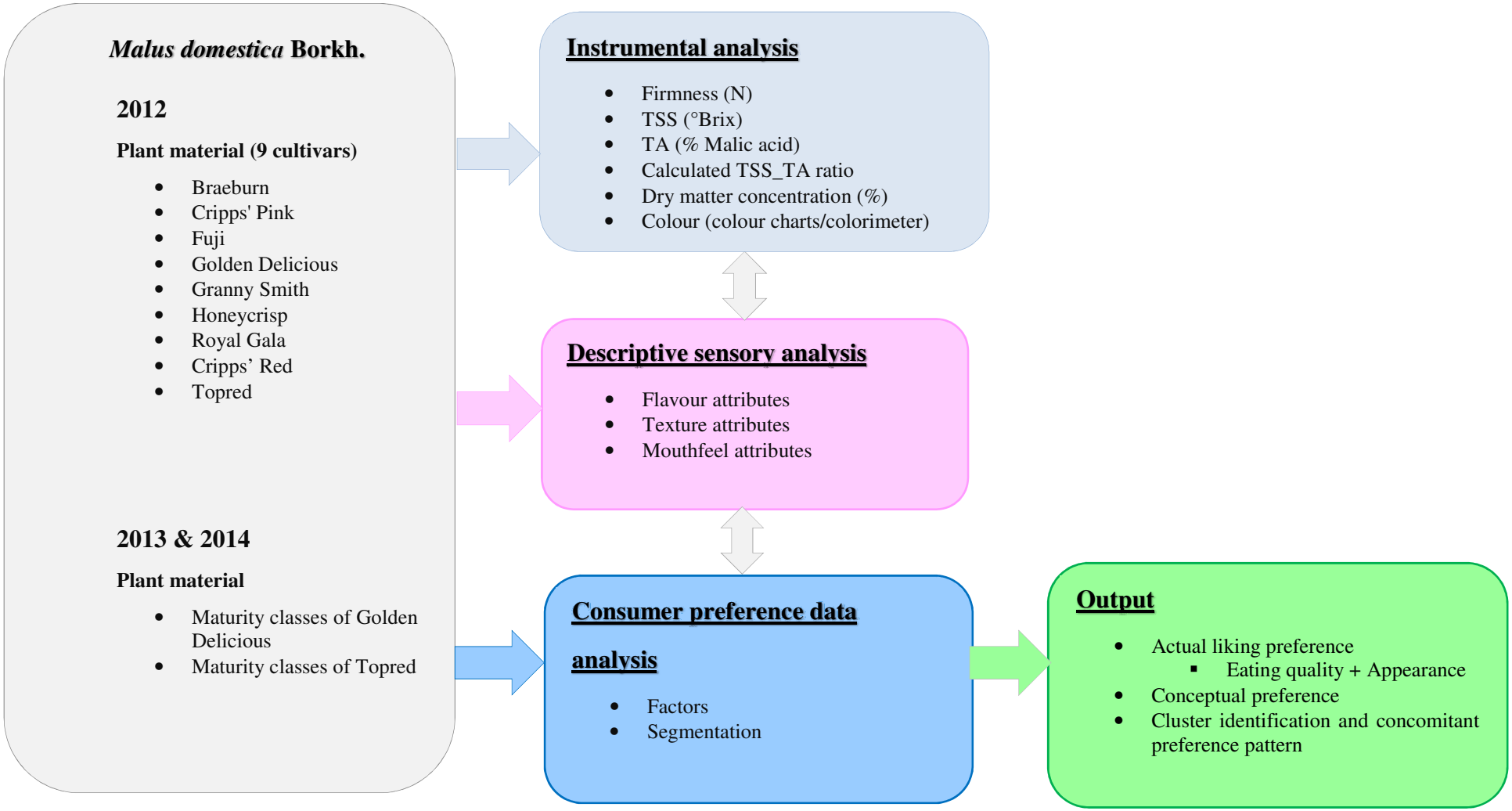

Fig. 1 Research framework of apple cultivars during 2012, 2013 and 2014

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LITERATURE REVIEW: APPLE QUALITY ATTRIBUTES AND CONSUMERS' PREFERENCE

Introduction

Apple quality

Components of apple quality

Consumer preference and eating quality attributes

Consumer preference and appearance factors

Purchase factors

Determination of apple quality and consumer preference by quantitative and qualitative means

Determination of apple quality using instrumental measurements

Apple quality determination using sensory means

Instrumental and sensory correlations

Preference mapping as a tool for determining consumer preference

Consumer segregation in preference for apple quality

Influence of ethnic group on preference for apple quality

Age group variations in apple quality preference

Gender differences in apple quality preference

Consumer clusters and apple quality preference

Apple ripening and consumer preference

Changes in internal and external characteristics of apples during ripening

Influence of ripening-related changes on consumer preference

Conclusions

Introduction

Apple quality can be defined by both intrinsic and extrinsic factors (Abbott, 1999), and consumer preference for each of these factors differ significantly (Harker *et al*., 2003). Eating quality attributes, appearance factors, as well as external components such as price, packaging and cultivar tend to influence consumer liking and ultimately purchase decisions (Crassweller and Hollender, 1989; Abbott, 1999; Racskó *et al*., 2009a, b). Consumer preference patterns can also be influenced by socio-demographic factors such as ethnicity, age and gender as well as socio-economic factors (Prescott and Bell, 1995; Harker *et al*., 2002). While some studies on consumer preference for eating quality attributes indicated preference differences between cultures (Druz and Baldwin, 1982; Prescott and Bell, 1995; Bonany *et al*., 2013), others did not (Jaeger *et al*., 1998; Cliff *et al*., 1999). British Columbian consumers differed from Nova Scotian consumers in their apple appearance preferences demonstrating regional apple preferences within Canada (Cliff *et al*., 1999). In South Africa, Van der Merwe (2013) found ethnic and age group differences among consumers of the Western Cape Province in terms of the drivers of apple eating quality and appearance preference. Generally, colour influences eating quality expectations and thus a high correlation between colour and eating quality could ensure consumer satisfaction and continued apple purchases (Harker *et al*., 2008; Steyn, 2012). When eating quality expectations based on fruit appearance are not met, consumers could stop buying that particular cultivar resulting in lower profitability (Steyn, 2012).

Establishing whether there are socio-demographic differences in apple eating quality and appearance preferences is of considerable importance in a multi-cultural society such as South Africa and thus formed the basis of the research reported in this dissertation. Therefore, this literature study focused on how the preferences of consumers of different ethnic, age groups and clusters relate to the components of apple quality. To facilitate the discussion, the components of apple quality were first defined. The physicochemical and sensory means of determining the levels of various quality attributes, their correlations and their relation to consumer preference formed the next section of the literature study. Information was also obtained on the factors that influence the purchase decisions of various consumer groups. Lastly, apples are alive and their eating quality is not static during the postharvest, shelf-life period. Since ripening-associated changes in apple quality attributes may significantly affect

consumer preference (Richardson-Harman *et al*., 1998; Varela *et al*., 2005), this was the focus for the last section of the literature study.

Apple quality

Components of apple quality

Quality is a complex term but can be defined as all the constituents of a product that ensures consumer satisfaction and acceptance of the product (Cardello, 1995). Apple quality consists of both intrinsic and extrinsic factors (Abbott, 1999). Intrinsic factors such as eating quality and appearance attributes associate directly with the fruit and can be assessed instrumentally as well as sensorially by looking, tasting or smelling the product in question (Daillant-Spinnler *et al*., 1996; Abbott, 1999). Extrinsic factors such as packaging, label, price, health benefits, origin, cultivar and organic production does not associate directly with the fruit and cannot be learned through the use of the human senses (Abbott, 1999; Racskó *et al*., 2009a, b; Yue and Tong, 2011; Moor *et al*., 2014). According to Stow (1995) and Daillant-Spinnler *et al*. (1996), apple eating quality is best described by texture, taste and flavour attributes. Texture consists of attributes such as hardness, crispness, crunchiness, juiciness, mealiness, sponginess and peel toughness (Daillant-Spinnler *et al*., 1996; Jaeger *et al.,* 1998; Galmarini *et al*., 2013). Sweetness and sourness constitute apple taste, while volatile compounds make up apple flavour (Abbott, 1999; Karlsen *et al*., 1999) which can be described by terms such as fresh apple, grassy, unripe apple, ripe, stale, old, alcohol, pear-like and soapy (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Varela *et al*., 2005). Astringency and bitterness constitute mouthfeel attributes (Daillant-Spinnler *et al*., 1996). The appearance of a product is characterised by colour, size, shape, form, condition and absence of defects (Kays, 1998). Each of the attributes mentioned influences the quality preferences and perceptions of apple consumers and/or consumer groups differently (Harker *et al*., 2003).

Consumer preference and eating quality attributes

Various studies have been conducted in different countries on eating quality attributes that drive consumer preference for apples (Table 1). Generally, consumers from the different countries seem to vary more with regard to positive drivers of liking while negative drivers seem to be more universal. Mealiness was a negative driver of liking in most of the studies and countries, with the exception of Poland (Konopacka *et al*., 2006; Bonany *et al*., 2013).

Consumers generally preferred firm apples with crispy and crunchy textures (Szczesniak and Kahn, 1984) and associated such textures with freshness and wholesomeness (Fillion and Kilcast, 2000). However, some consumers prefer softer apples, as evident in the preference of Spanish and Polish consumers (Bonany *et al*., 2013). According to Harker *et al*. (2002a and 2008), in addition to firmness, sweetness and sourness also play a large role in defining eating quality for specific apple cultivars. European and Canadian apple consumers' general taste and flavour preference for apple eating quality was driven by sweet taste, moderate sour taste and high apple flavour while a strongly acidic taste was generally disliked (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Cliff *et al*., 1999; Andani *et al*., 2001; Bonany *et al*., 2013). However, consumers in Germany, and to an extent those in the Netherlands and Switzerland, preferred cultivars with high acidity levels (Bonany *et al*., 2013). Consumers in Portland, USA liked sour taste in addition to firmness but disliked high sweet taste (Harker *et al*., 2008). The only study conducted on South African consumers' apple quality preferences showed that the preference of consumers in the Western Cape was generally driven by sweet taste (Van der Merwe, 2013).

Table 1 Consumers of different countries and their general preferences and dislikes regarding apple eating quality attributes.

Country	Likes	Dislikes	Reference
UK	Firmness Crispness Juiciness Sweet taste	Sponginess Mealiness Soapy Off-flavour	Daillant-Spinnler *et al*. (1996)
UK and Denmark	Crispness Hardness Crunchiness Sweet taste Apple flavour Fruity flavour	Strong acidic taste Astringent Off-flavour Mealiness	Jaeger *et al*. (1998)
Canada	Firmness Juiciness Sweet taste Low to medium	Soft texture Mealiness	Cliff *et al*. (1999)

	acidity		
Poland	Firm Juicy Ripe apple flavours	Soft texture Less juicy Sourness Astringent	Konopacka *et al.* (2006)
Spain and Poland	Sweet taste Soft texture	Sour taste Firmness	Bonany *et al.* (2013)
Portland, USA	Crispness Juiciness Sour taste	Soft texture High sweet taste Mealiness	Harker *et al.* (2008)
France	Sweet taste Crunchiness	Mealiness	Symoneaux *et al.* (2012)
France and Italy	Sweet taste Firmness Medium to low acidic taste	High acidic taste Softness Mealiness	Bonany *et al.* (2013)
Germany	Crispness Juiciness High acidic taste	Sweet taste Mealiness	Bonany *et al.* (2013)
Switzerland and The Netherlands	Sweet taste High acidic taste Firmness	Softness Mealiness	Bonany *et al.* (2013)
Western Cape, South Africa	Sweet taste Firmness (white consumers) Sour taste (white consumers)	Sour taste (black and coloured consumers) Mealiness (white consumers)	Van der Merwe (2013)

Consumer preference and appearance factors

Consumers will only continue to buy apples if satisfied with the eating quality (Harker *et al.*, 2008). However, consumers' perception of fruit quality prior to tasting is influenced by visual appearance and especially peel colour (Barrett *et al.*, 2010). Peel colour is considered one of the most important factors that influence consumer preference for apple quality and

ultimately fruit sales (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002) because peel colour provides information about the ripeness of apple and its potential taste (Richardson-Harman *et al*., 1998; Steyn, 2012). Spence *et al.* (2010) reported that colour interferes with the judgment of flavour intensity and identification of foods and hence dramatically influences the pleasantness and acceptability of food. Substantial improvement in apple appearance, especially in terms of fruit colour and size, has played a large role in enhancing fruit sales (Crassweller and Hollender, 1989). Dobrzański and Rybczyński (2008) reported that colour liking depends on the uniformity of the external colour, physical defects, dents, browning, bruising, saturation of blush, intensity of the background colour and its lightness or darkness. In apple peel, a blend of chlorophylls and carotenoids as well as anthocyanins, depending on cultivar, is responsible for the fruit colour (Lancaster *et al*., 1994). Consumers have come to accept that, within a cultivar, redder apples are sweeter than greener apples due to their higher sugar content and more flavour, which is linked to the ripeness and/or the light exposure of the fruit (Saure, 1990). Hamadziripi *et al*. (2014) showed that the extent of the red colour correlates with the internal quality, consumer preference for taste and potential health value through higher levels of anthocyanins, ascorbic acid, phenolic compounds and higher antioxidant capacity of Starking apples. Daillant-Spinnler *et al*. (1996) found that unpeeled red apples were generally associated with sweet descriptors while unpeeled green apples were concomitant with sour descriptors. Van der Merwe *et al*. (2015) showed that the appearance of the trademark cultivar Pink Lady™ influenced its eating quality expectations positively for consumers in the Western Cape region of South Africa. Gamble *et al*. (2006) indicated that different groups or segments of consumers differ in what they consider as acceptable in relation to fruit appearance. Cliff *et al*. (2002) found that New Zealand consumers preferred striped apples, consumers in Nova Scotia, Canada preferred blushed apples, while consumers in British Columbia, Canada were more accepting of a range of apple appearances.

The association between fruit colour and eating quality depends on consumers' familiarity with the fruit, as evident from the following examples. Hawaiian consumers preferred fresh, juiced or canned products of Del Monte Hawai`i pineapple, a yellower cultivar, to Smooth Cayenne (Ramsaroop and Saulo, 2007), probably due the association of yellow colour with increased maturity, ripeness and sweetness (Richardson-Harman *et al*., 1998). British consumers may associate a brown-coloured drink with the taste of cola, expecting sweetness

and would therefore show disapproval if presented with a sour brown coloured drink (Shankar *et al.*, 2010). Taiwanese consumers on the other hand, may associate a brown-coloured drink with the slightly acidic taste of grape juice and their expectations would be confirmed when they are presented with an acidic brown-coloured drink.

Purchase factors

The findings of various studies that investigated factors that influenced consumer purchase decision for fresh apples are summarized in Table 2. Steenkamp (1989) indicated that consumers generally place a greater premium on intrinsic quality factors associated with the product itself than on extrinsic factors such as product brand or price. A higher percentage (80%) of British consumers' decision to purchase fruit was based on fruit quality attributes such as crispness and sweet taste rather than on price (Market Review, 1996). On the contrary, 60% of French consumers placed a premium on price (Alavoine *et al.*, 1990). German consumers stated freshness of a fruit or vegetable as the most important purchase factor (AgV, 1981), while factors such as taste, aroma and freshness were the most important factors that influenced Swiss consumers' choice of apple (Péneau *et al.*, 2006). Swiss consumers' perception of freshness was in close association with their perception of taste, crispness and juiciness (Péneau *et al.*, 2006). Apple fruit appearance was, however, of less importance in relation to Swiss consumers' perception of quality (Péneau *et al.*, 2006). Age group played a significant role in the purchase decision of Hungarian consumers (Racskó *et al.*, 2009b). Consumers in the <25 years age group indicated that taste was the most important attribute that influenced their choice of apple followed by fruit size and colour (Racskó *et al.*, 2009b). Cultivar and origin were not important factors in the apple choice decision of Hungarian consumers. Australian consumers' decision to purchase a specific apple was influenced by apple quality attributes such as fruit safety (Kirchhoff *et al.*, 2008). Apple peel colour was the most important purchase factor for all ethnic and age groups of South African consumers in the Stellenbosch area of the Western Cape Province (Van der Merwe, 2013). In the latter study, black and coloured consumers also indicated that fruit size and price influence their purchase decisions, while white consumers associated with cultivar loyalty and cultivar name indication on the packaging (Van der Merwe, 2013). The purchase decisions of consumers ranging in age from 18 to 25 years associated with colour and size, while price and cultivar loyalty were the most important purchase factors for consumers aged 26 and older. The association of black consumers with price in terms of their purchase

decision is probably because in that study they may have generally belonged to lower socioeconomic groups (Johansson and Anderson, 1998; Wortley and Tshwaedi, 2002; Holborn, 2012). Poorer consumers proportionately spend more of their disposable income on food and are therefore more price sensitive (Wortley and Tshwaedi, 2002; Holborn, 2012).

Table 2 The primary factors that influence the purchase decisions of consumers of different countries.

Country	Important purchase factors	Reference
UK	Hardness Juiciness Sweetness	Market Review (1996)
France	Price	Alavoine *et al*. (1990)
Germany	Freshness of fruit	AgV (1981)
Switzerland	Fruit taste Aroma Freshness	Péneau *et al*. (2006)
Hungary	Taste Fruit size Colour	Racskó *et al*. (2009)
Australia	Fruit safety	Kirchhoff *et al*. (2008)
South Africa	Peel colour Fruit size Price Cultivar loyalty Cultivar name indication on packaging	Van der Merwe (2013)

Determination of apple quality and consumer preference by quantitative and qualitative means

Determination of apple quality using instrumental measurement

Instrumental measurement of quality-related attributes is mostly preferred over sensory means of quality assessment because of its objectivity, accuracy and usefulness in measuring product quality on a regular basis (Shewfelt 1993; Abbott, 1999; Barrett *et al*., 2010). In

addition, product quality determination using sensory analysis is regarded as being time-consuming (Mehinagic *et al*., 2004). However, quality measurement by instrumental means is limited in relation to indicating how consumers perceive what is acceptable in terms of quality (Abbott, 1999). Since product quality should be aimed at ensuring consumer satisfaction, the use of instrumental measurements, as well as sensory methods for quality evaluation must be complimentary (Abbott, 1999; Harker *et al*., 2002a, b). A combination of physical, chemical and sensory means of product evaluation provides an indication of the overall quality of a product or commodity in relation to consumer preference (Heintz and Kader, 1983).

The most commonly assessed instrumental measurements of internal fruit quality are total soluble solids (TSS), titratable acidity (TA) and flesh firmness (Harker *et al*., 2002a, b). Instrumental measurement of TSS in °Brix using a refractometer has proved effective in detecting the sugar content of ripe fruit (Harker *et al*., 2002b). Harker *et al*. (2002b) emphasised that although the measure of TSS was the best and most effective in predicting sensory sweetness of apple fruit, it is generally difficult to predict sweet taste using instrumental methods. TA is determined by titrating an amount of juice from each sample with a standard base such as NaOH to a specified pH value (Watada, 1995). Harker *et al*. (2002b) showed that instrumental measurement of TA is the best predictor of apple fruit sensory sour taste. Owing to the concealing effect that sweetness and sourness tend to have on each other, intensity of sweetness or sourness in relation to consumer acceptability may be best described by the calculated sugar to acid ratio (Jones and Scott, 1983; Harker *et al*., 2002b). Although the use of penetrometers fitted with an 11 mm diameter probe are the most accurate sensory texture attribute predictor, instrumental tests in general could not detect all textural differences between apples at all times (Harker *et al*., 2002a). In addition, Barreiro *et al*. (1998) and Mehinagic *et al*. (2004) recommended the use of confined compression tests for juiciness and mealiness prediction. Palmer *et al*. (2010) found dry matter concentration (DMC) an effective fruit quality determinant and a reliable predictor of TSS and to a certain extent fruit firmness. DMC also proved an important measure of fruit quality for outer canopy fruits of ‘Starking’, ‘Golden Delicious’ and ‘Granny Smith’ (Hamadziripi *et al*., 2014). However, DMC did not provide accurate indication of fruit quality for both inner and outer canopy ‘Forelle’ pear fruits (Cronje *et al*., 2015). DMC is determined by weighing a

fresh sample of fruit, which is then oven dried until a constant weight is attained. DMC is then calculated as dry weight as a percentage of fresh weight.

Apple peel colour can be assessed objectively using a colorimeter or measured slightly more subjectively using a colour chart. According to Hunt and Pointer (2011), the colorimeter is used in measuring colour in dimensions of hue, colourfulness and brightness. Lightness describes the brightness of objects relative to that of a similarly illuminated white tile, while colourfulness relates to the amount of hue that an area exhibit and thus colour purity. The perceived colourfulness in relation to a similarly illuminated white tile is termed chroma. Hue angle is the attribute of visual perception according to the differential absorbance, reflection or transmittance of light of different wavelengths in the visible spectrum. While colour measurement by colorimeter is objective, it has some downsides. The aperture of colorimeters allows colour measurement of a circle of apple peel with a diameter of only 8 mm, which does not reflect the overall appearance of the fruit. In addition, knowledge of hue angle, chroma and lightness values is needed in order to interpret colorimeter data. Colour charts are used to assess foreground as well as background colour. Background colour in apples from green to yellow is a maturity indicator while foreground red blush colour is used to grade fruit into different classes (Steyn, 2012). For some cultivars, fruit need to have a certain minimum red foreground colour to be graded to the highest value classes. For example, 'Cripps' Pink' fruit with more than 40% blush colour can be marketed as Pink Lady® (Hurndall and Fourie, 2003). At between 10-40% blush colour, the fruit are marketed under their Cripps' Pink cultivar name while at <10% colour, the fruit are downgraded for processing. Various charts are used commercially to assess the levels or incidence of various cosmetic disorders of the apple peel, for example russetting, sunburn, red blush in 'Granny Smith', malformation, etc.

Apple quality determination using sensory analysis

Sensory assessments are regarded an integral part of apple quality determination because although instrumental tests are fast and result in objective and accurate assessment of the physical composition of a product, instrumental tests fail to adequately and consistently predict what consumers perceive as acceptable in terms of quality (Harker *et al*., 2002a; Abbott *et al*., 2004). Unlike instrumental tests, sensory analysis employs the use of human senses of sight, taste, touch, smell and hearing (Martínez, 2007). Human subjects act as

judges during sensory analysis procedures and panellists are trained for descriptive sensory analysis to enable them detect variations in sensory attributes in food products (Heintz and Kader, 1983; Lawless and Heymann, 2010). According to Williams and Carter (1977), descriptive sensory analysis deals with profiling a product on all of its perceived sensory attributes (Murray *et al*., 2001). Sensory profiling of 12 Southern Hemisphere apples by Daillant-Spinnler *et al*. (1996) resulted in a useful baseline descriptive sensory analysis method for evaluating the eating quality of fresh apples. Jaeger *et al*. (1998), Andani *et al*. (2001), Kühn and Thybo (2001), as well as Van der Merwe (2013) based descriptive sensory analysis in the respective studies on terms and procedures developed by Daillant-Spinnler *et al*. (1996). Descriptors used in sensory profiling of different apple cultivars are summarised in Table 3. Generally, attributes such as juiciness, hardness, crispness and mealiness best described the texture of most of the fruits tasted by a trained panel while sweet taste, sour taste and apple flavour best described the taste/aroma component. Perceived slimy texture as well as old, stale and off-flavours were characteristic of mealiness-based studies (Barreiro *et al*., 1998; Jaeger *et al*., 1998; Andani *et al*., 2001).

Table 3 Descriptors used in profiling perceived sensory attributes of apples

Plant Material	Texture	Flavour (Taste/Aroma)	Mouthfeel	Appearance	Reference
Twelve apple cultivars from the Southern Hemisphere	Juiciness Crispness Hardness Spongy Peel toughness	Sweet taste Sour taste Unripe taste Fresh flavour Soapy flavour Off-flavour Pear-like flavour	Astringency	Shiny appearance	Daillant-Spinnler *et al*. (1996)
Three apple cultivars Boskoop, Cox's Orange Pippin and Jonagold	Juiciness Crispness Hardness Density of flesh Toughness Granular Fibrous Floury Pulpy Slimy	Sweet taste Sour taste Apple flavour Green apple flavour Red apple flavour Unripe apple flavour Stale Watery flavour Cooked apple	Bitterness Astringency Residue after swallow	Internal colour	Barreiro *et al*. (1998)
Three apple cultivars Belle de Boskoop, Cox's Orange Pippin and Jonagold from Belgium	Juiciness Crispness Hardness Granular Floury Pulpy Slimy	Sweet taste Sour taste Fruity flavour Floral flavour Grassy odour Pear-like flavour Red apple flavour Unripe odour Old, stale flavour Cooked apple	Bitterness Astringency Residue after swallow	Green appearance Fluffy appearance	Jaeger *et al*. (1998)
Thirteen apple cultivars (10 from	Juiciness Crispness	Sweet taste Sour taste	Bitterness		Karlsen *et al*. (1999)

Norway, 2 from The Netherlands and 1 from France	Hardness Mushiness Chewiness	Fruity flavour Grassy flavour Honey flavour Bitter odour			
Three apple cultivars Belle de Boskoop, Cox's Orange Pippin and Jonagold from the Northern Hemisphere	Juiciness Crispness Hardness Granular Fibrous Floury Slimy	Sweet taste Sour taste Unripe apple flavour Old, stale flavour Pear-like flavour Plum/cherry flavour Red apple flavour Cider flavour	Astringency Bitterness Residue after swallow	Green internal appearance Yellow internal appearance Juicy internal appearance Fluffy internal appearance	Andani *et al*. (2001)
Six apple cultivars from Denmark	Juiciness Crispness Hardness Peel toughness Mealiness	Sweet taste Sour taste Apple flavour Unripe flavour Perfumed flavour Overripe flavour			Kühn and Thybo (2001)
Nine apple cultivars from South Africa	Juiciness Crispness Crunchiness Peel toughness Mealiness	Sweet taste Sour taste Apple flavour	Astringency Bitterness		Van der Merwe (2013)

Instrumental and sensory correlations

Szczesniak (1987) and Shewfelt (1999) showed that correlating sensory perception and instrumental measurement is useful for envisaging consumer responses or for evaluating quality control parameters. Correlating physical measurements with related sensory attributes gives an indication of variation within a product, but also whether instrumental data can be used to predict specific sensory quality attributes effectively (Lawless and Heymann, 2010). Relationships among chemical and physical properties of a commodity and its sensory qualities can thus be identified by correlating outcomes of sensory analysis with corresponding results from chemical and physical measurements (Heintz and Kader, 1983). Instrumental firmness has been found to correlate significantly with sensory texture attributes in some experiments but not in others because differences in product quality tends to influence the nature and extent of correlation between sensory and instrumental measurement (Szczesniak, 1968; Harker *et al*., 2006). However, Mehinagic *et al*. (2004) showed that associations between sensory attributes and their corresponding instrumental variables are not always constant, and may change from one group of cultivars to another. Instrumental measurements could not adequately predict the related sensory attributes in studies of Van der Merwe (2013).

Daillant-Spinnler *et al*. (1996) and Jaeger *et al*. (1998) showed a negative correlation between instrumental firmness using puncture tests and the sensory texture attribute mealiness. Sensory hardness as rated by trained panel was highly correlated with instrumental firmness in studies of Paoletti *et al*. (1993) and Karlsen *et al*. (1999) when a number of apple cultivars were evaluated. Bonany *et al*. (2014) also found significant positive correlations between instrumental firmness and sensory hardness. The sensory texture attributes, crispness, hardness and toughness were positively and highly correlated but associations of mealiness, juiciness and sponginess with crispness, hardness and toughness were not consistent for all the cultivars tested (Abbott *et al*., 1984; Mehinagic *et al*., 2004).

There are also important relationships between objective and sensory measurements of apple taste and flavour. Thiault (1970) and Harker *et al*. (2002b) showed that TA is the best predictor of sour taste. Bourne (1979) and Watada *et al*. (1981) found poor correlations between TSS, TA and fruit firmness with their corresponding sensory attributes, sweetness,

sourness and crisp/hard texture. In contrast, Bonany *et al*. (2014) found significant positive correlations between TA, TSS and their corresponding sensory attributes, sourness and sweetness. Van der Merwe (2013) indicated that although TSS is often used in predicting the sensory perception of sweetness, TSS/TA ratio is a more valuable measurement for predicting sweetness. This is because TSS/TA accounts for the effect of acidity on sweet taste perception (Van der Merwe, 2013). The sensory texture attribute mealiness correlated positively with off-flavours, overripe fermented flavour, alcoholic flavour and odour (Jaeger *et al*., 1998; Varela *et al*., 2005), as well as with TSS and TA ratio (Jaeger *et al*., 1998) but negatively with apple flavour (Jaeger *et al*., 1998), juiciness, sour taste and hardness (Harker *et al*., 2002a; Bonany *et al*., 2014).

Preference mapping as a tool for determining consumer preference

Preference mapping is a statistical tool that can account for differences in consumer liking for the same product, since consumers tend to differ in terms of what is considered acceptable quality. Preference mapping consists of internal and external analyses (Carroll, 1980). Internal preference mapping deals with only consumer preference data. With external preference mapping, the map is created from consumer hedonic responses, and then instrumental or sensory attributes are projected onto the map according to correlation against the preference dimensions, primarily to ascertain the positive and negative drivers of liking (MacFie and Hedderley, 1993). Consumer groups with similar liking scores, but which differ from other groups in terms of culture, age, gender, attitudes, eating habits, socio-economic backgrounds and/or reaction towards product characteristics can be identified using preference mapping (Westad *et al*., 2004). Consumer groups with different preference and consumption patterns can be also identified using preference mapping techniques (Helgesen *et al*., 1997).

Segmentation techniques can be used in identifying groups of consumers with similar preference patterns (Carbonell *et al*., 2008). Vigneau *et al*. (2001) showed that segmenting a population of consumers into various groups that differ in their preference pattern is a very useful aspect of preference studies because, average hedonic values indicate general drivers of consumer liking, but do not give information about the preference patterns of groups of consumers (Carbonell *et al*., 2008). Consumer segmentation procedure can also be carried out

by relating consumers' socio-demographic and socio-economic variables to the preference data generated from consumers' liking scores (Helgesen *et al*., 1997; Thybo *et al*., 2003). Segmentation procedures could preferably be based entirely on the use of preference data generated by the consumers' who carried out product testing on same fruit samples and under same conditions of testing (Vigneau *et al*., 2001; Santa Cruz *et al*., 2002; Jaeger *et al*., 2003). Consumer segmentation procedures can also be done by applying cluster analysis to mean centred preference data (Carbonell *et al*., 2008; Van der Merwe, 2013).

Consumer segregation in preference for apple quality

Consumers' preference for taste, texture, appearance and aroma, as well as for non-sensory factors that influence their preference decisions can be complicated (Prescott, 1998). This is because factors such as ethnic differences (most dominant factor), age, gender, education, income level and even memory of how an apple tasted on previous occasions may influence consumers' preference patterns (Prescott and Bell, 1995; Harker *et al*., 2002). Jaeger and Rose (2008) have indicated that choice of food is strictly behavioural. Differences among individuals within the same socio-demographic group could be so wide that overlap between consumers from different groups is unavoidable (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Kühn and Thybo, 2001). In addition, consumers of similar socio-demographic backgrounds do not necessarily exhibit the same preferences and may respond differently to marketing variables (Daillant-Spinnler *et al*., 1996; Richards, 2000). Determining consumers or groups of consumers in relation to their response to apple quality attributes and targeting such groups with their most preferred cultivars could increase apple sales substantially (Harker, 2001).

Influence of ethnic group on preference for apple quality

Cultural factors have a substantial influence on food choice and consumption (Prescott and Bell, 1995; Rozin, 1996). However, the effect of ethnic group on food preference is not clearly understood (Pangborn *et al*., 1988). British and Danish consumers did not differ in their preference of apples with varying mealiness levels, thus not supporting the authors' hypothesis of cross-cultural differences in preference of apple eating quality (Jaeger *et al*., 1998). Viljoen and Gericke (2001a) showed that coloured and white consumers in South Africa had similar general food preferences that could be described as European-like. The

food preference pattern of black consumers in South Africa, however, differed from that of coloured and white consumers (Viljoen and Gericke, 2001b).

Prescott (1998) observed that food taste preferences and perceptions differed between Japanese and Australian consumers. These differences were ascribed to consumers' familiarity with test products rather than inherent differences in sensory perception (Prescott, 1998). Samoan consumers' resident in New Zealand, being more communal-oriented, perceived an apple product intended for home consumption as ideal while consumers' native to New Zealand preferred apple packs designed for consumption while out of home and considered such packs as ideal owing to their individualistic nature (Jaeger, 2000). Bonany *et al*. (2013) showed country and cultivar interaction in their study that focused on evaluating apple cultivar preference and acceptance of consumers in Spain, Poland, Germany, Italy, The Netherlands, France and Switzerland. German and to some extent Dutch and Swiss consumers preferred cultivars with a high sour taste while consumers from the other countries generally preferred sweet tasting, firm cultivars with low to medium acidity levels. Cliff *et al*. (2014) found that the majority (88%) of Canadian consumers from Asian descent preferred sweet tasting cultivars. In contrast, Canadian consumers from European descent liked both sweet (55%) and sour (45%) tasting cultivars. Flavour attributes such as sweet taste were important drivers of liking for black and coloured consumers of the Western Cape Province of South Africa (Van der Merwe, 2013). These consumers seemed to tolerate mealiness but disliked sour taste and differed from white consumers who gave higher preference scores for firm and sour cultivars. White consumers had a strong aversion to mealiness.

In terms of appearance, Cliff *et al*. (2014) found that Canadian consumers from Asian and European descent who had higher preference for sweet taste, preferred apples with red peel colour significantly more, but had a strong aversion to green apple peel colour. Bi-coloured apples with a green background colour were disliked while bi-coloured apples with a yellow background and red overcolour were preferred. The sour liking consumers, mainly of European descent, preferred the appearance of green apple peel colour. Black and coloured consumers of the Western Cape Province of South Africa liked the appearance of full and striped red apples and this is in close association with their preference for sweet taste (Van der Merwe, 2013). However, black and coloured consumers disliked the appearance of

'Granny Smith', with this cultivar also closely associating with sour taste. White consumers preferred the appearance of firmer fruit such as 'Pink Lady'® and 'Granny Smith', which associated closely with their preference for high apple flavour, sour taste and firm texture.

Age group variations in apple quality preference

Prescott and Bell (1995), as well as Harker *et al*. (2002) indicated that in addition to ethnic differences, consumers' age are also likely to affect preference patterns substantially. Taste sensitivity and preferences may change as consumers' age (De Graaf *et al*., 1994). The lower preference for sour apples among Dutch consumer group above 55 years, compared to the younger generation was due to the decrease of human chemosensory ability with age (Schiffman, 1986). Therefore, consumers' apple eating quality preferences may change over time (De Graaf *et al*., 1994; Harker *et al*., 2002). Moor *et al*. (2014) hypothesised that large differences in apple preference among Estonian generations may be due to the exposure of younger people to both domestic and imported apples while the older generation may have only ate domestic apples when they were young. It is widely known that childhood eating habits are important determinants of adult eating behaviour (Woodward *et al*., 1996). Péneau *et al*. (2006) found that Swiss consumers between the ages 15 and 70 gave similar importance ratings for taste, aroma and freshness. Young Swiss consumers younger than 30 rated the importance of apple fruit appearance significantly higher than the type of cultivar as well as if fruit was organic or not. Whether apples were organic or not was most important to Swiss consumers between the ages of 30 and 60. Evaluating Hungarian consumers' preference for apple cultivars grown in five different countries viz. Argentina, Chile, South Africa, Hungary and Austria, Racskó *et al*. (2009a) showed that children and young consumers (< 25 years) preferred 'Royal Gala', 'Granny Smith' and 'Braeburn'. These cultivars were the firmest cultivars and associated with red and green peel colours, respectively. Middle-aged Hungarian consumers (25-50) liked crispy apples with red or mottled red peel colour such as 'Royal Gala' and 'Jonagold'. Older consumers (>50) liked red 'Jonagold' and 'Idared' apples, probably because these cultivars were the cheapest. Bonany *et al*. (2013) found that older consumers (61-70) liked 'Golden Delicious', which associated with lower firmness (49 N), significantly more compared to younger consumers (15-35). Kühn and Thybo (2001) showed that children (9-13) liked the taste and appearance of fully blushed red 'Gala'. The taste of semi-blushed red 'Jonagold' and 'Elstar' as well as the appearance of fully blushed red 'Gloster' was also preferred. Older consumers (>50) also preferred the taste and

appearance of red 'Jonagold' and 'Idared' apples (Racskó *et al*., 2009a). Van der Merwe (2013) showed that young (18-25) consumers in the Western Cape Province of South Africa liked the eating quality of firm, sour cultivars and the appearance of green 'Granny Smith'. Older consumers (36+) preferred the eating quality of sweet tasting cultivars and the appearance of full red and striped red apple peel colours. Contrary to the above findings, Jaeger *et al*. (1998) found no age effect on the preference of British and Danish consumers for apple cultivars Boskoop, Cox and Jonagold with different mealiness levels. Hampson *et al*. (2000), in a study that focused on using sensory analysis as a selection tool in apple breeding in British Columbia, Canada, also found no influence of age on apple liking scores. Abbott *et al*. (2004) found minimal age and gender differences in their study that focused on consumers' assessment of fresh-cut slices of four apple cultivars, viz. Fuji, Golden Delicious, GoldRush and Granny Smith.

Thompson *et al*. (1999) found that 62% of young (16-24 years) consumers as compared to 36% of older (45-74 years) consumers were classified as low consumers of fruits and vegetables. Konopacka *et al*. (2010) showed that older consumers (61-70) consumed apples more often than middle-aged consumers (36–60) did and apple consumption was not very popular within the youngest consumers (16–35). Younger (<40 years) Swiss consumers consumed apples less frequently compared to older (> 40 years) consumers (Péneau *et al*., 2006). Bonany *et al*. (2013) indicated that young consumers are likely to consume more apples if they are targeted with crunchy and juicy fruits that maintain texture quality over prolonged shelf-life periods.

Gender differences in apple quality preference

In general, gender dissimilarities tend to influence several decision-making processes (Tashakkori, 1993; Franke *et al*., 1997; Powell and Ansic, 1997). Earlier studies that focused on the health and lifestyle of English consumers in relation to their fruit and vegetable intake showed that males were low consumers of fruit and vegetables compared to female consumers (Thompson *et al*., 1999). Rural African American women consumed more fruit and vegetable compared to rural African American men (McClelland *et al*., 1998). Reynolds *et al*. (1999) also observed a difference with respect to gender in the consumption of fruits and vegetables in a study that sought to examine the association between gender and

ethnicity. More girls than boys in Georgia, USA, consumed more fruits and vegetables. Evaluating the association between nutrition knowledge and food intake, Wardle *et al*. (2000) showed that the intake of fruit and vegetables was higher in women compared to men. Baker and Wardle (2003) in ascertaining the influence of gender on fruit and vegetable consumption in older adults in the United Kingdom confirmed that men consume less fruit and vegetables compared to women. They ascribed their finding to the fact that men usually have a lesser knowledge of the health-related nutritional benefits that a person could gain from consuming fruit and vegetables. With a total of 3.5 servings a day for female participants as compared to 2.5 servings a day for male participants, only 16% of men compared to 34% of women consumed the recommended daily servings of fruit and vegetable (Baker and Wardle, 2003). Girls in West London, in the United Kingdom, liked fruit and vegetables more than the boys did (Cooke and Wardle, 2005). The significantly higher preference of women for organic apples compared to men was also attributed to greater health consciousness in women than men (Duvigneaud *et al*., 2007). Konopacka *et al*. (2010) showed that in Europe, irrespective of country, more women than men indicated that they ate apples more frequently. Studies of Péneau *et al*. (2006) that evaluated Swiss consumers' perception of freshness of apples showed that characteristics including gender influences apple quality preferences. Twice as more women than men in Switzerland tend to consume apples frequently (Péneau *et al*., 2006). In addition, Swiss female consumers' importance ratings for attributes such as apple taste, aroma, freshness, appearance, type of cultivar, organically produced fruit was higher compared to male consumers (Péneau *et al*., 2006). However, fruit size was of higher importance to male consumers when making a decision to purchase apples than female consumers (Péneau *et al*., 2006). Studies of Thybo *et al*. (2003), which focused on assessing the preference of Danish children (6-10 years) for apple quality, showed that the taste and appearance preference of girls differed from that of boys. Contrary to the preference pattern of boys, girls liked the taste of red apples but preferred the appearance of green apples. Older women did not like the spicy flavoured, very sweet and very sour 'GoldRush' much (Janick, 2001; Abbott *et al*., 2004), while older men liked the sour, firm, juicy and poorly flavoured 'Granny Smith' less compared to other consumer groups and cultivars used during the study (Abbott *et al*., 2004).

Consumer clusters and apple quality preference

Cluster analysis of consumer preference data can indicate whether there are clusters of consumers that prefer specific sensory attributes in a product range (Lawless and Heymann, 2010). Internal preference mapping showed that the preference of British and Danish consumers for apples of varying mealiness levels was closely associated with cultivar rather than mealiness level (Jaeger *et al*., 1998). Internal preference mapping studies of Jaeger *et al*. (1998) identified two consumer segments based on cultivar liking. One consumer segment had a higher preference of fresh 'Jonagold' apples and the other had higher liking for 'Cox' apples. Both cultivars however, associated with sweetness and fruity flavour. Three main dimensions were generated when Bonany *et al*. (2014) applied preference mapping methodology to apple cultivars in Europe. The first component associated with instrumental firmness and acidity, as well as sensory hardness and sour taste. The second component correlated positively with sweet taste, fruity and flowery flavour and minimally with instrumental measure of sugar content but negatively with acidic or sour characteristics. The third component positively associated with juiciness and crispness but dissociated with mealiness.

Daillant-Spinnler *et al*. (1996) by dividing preference maps into quadrants with different consumer groups assigned to specific quadrants, showed that British consumers were segmented into two groups with approximately equal proportions of consumers in each group. One group preferred sweet, hard apples, which was evident in their preference for 'Fuji', while the other group liked juicy, sour apples and was apparent in their preference for 'Granny Smith'. Vigneau and Qannari (2002) also identified two groups of French consumers with differing preference pattern for apple eating quality using a clustering approach. The first group had twice as many consumers as compared to consumers in the second group and associated with firmness factors such as juiciness and crisp texture, as well as acid/green flavour (sourness) and a dislike for spongy texture. The preference pattern of the first group was evident in their liking of 'Braeburn', 'Granny Smith' and 'Aurora'. The second group associated more with flavour attributes such as sweet taste and preferred 'Compact Golden Delicious', 'Royal Gala' and 'Fuji'. They had an aversion to sour taste and therefore disliked 'Braeburn' and 'Granny Smith'.

Employing the use of comment analysis to evaluate consumers' preference for apple eating quality, Symoneaux *et al*. (2012) identified two groups of French consumers with approximately equal proportions of consumers in each group. The identified consumer groups either preferred sweet, crunchy apples or disliked sour taste. Thus, a higher proportion of French consumers in studies of Vigneau and Qannari (2002) liked sour taste but French consumers in studies of Symoneaux *et al*. (2012) disliked sour taste. Carbonell *et al*. (2008), through the application of Ward's clustering analysis to preference data, obtained four different Spanish consumer groups with almost 30% of the total consumers liking crispy, hard apples with sour taste and disliking sweet taste and mealy apples, and 22% liking sweet taste, tolerating mealiness, but disliking sour taste. Twenty-eight percent of the consumers' liking was situated between sweet taste and mealiness. The preference of the remaining 20% was situated between juiciness and sour taste. Tomala *et al*. (2009) identified three consumer clusters with distinct preference patterns in the study that focused on evaluating children (6-8 years), youngsters (9-15 years) and adult (> 16 years) Polish consumers' preference for scab-resistant apple cultivars as against their acceptance of conventional apple cultivars. Cluster 1 constituted non-discriminating consumers who preferred all apples tested considerably and to the same extent. Consumers in the second cluster preferred firm, juicy and acidic apples, while cluster 3 consumers liked sweet apples with distinctive ripe apple flavour and moderate firmness. Cluster 1 had the highest representation of children (41%) in 2005 and the lowest representation of adults (17%) in 2004. Cluster 2 had an overrepresentation of adults (49%) in 2005 and young (48%) consumers in 2004. Cluster 3 had the highest representation of adults (51%) and children (46%) in 2004. Seppä *et al*. (2013) identified three groups of Finnish consumers when segmentation was based on ideal apple descriptors. Cluster 1 (24%) preferred sweet and soft/mealy apples, cluster 2 (33%) preferred hard and sour apples, while cluster 3 (43%) had a predilection for medium sweet and medium sour apples. Using the clustering of incomplete preferences (CLIP) technique in the most comprehensive study to date, Bonany *et al*. (2014) identified six different clusters grouping into two main mega clusters among consumers of seven European countries viz. France, Netherlands, Germany, Poland, Switzerland, Italy and Spain. Mega cluster A (clusters 1, 2, 5 and 6) which constituted 68% of consumers associated with sweetness, while mega cluster B (clusters 3 and 4) made up of 32% of consumers preferred acidic-firm apples. Cluster 1 comprising 21% of consumers' preferred sweet taste, liked juiciness and crispness moderately but disliked acidity to some extent. Clusters 2 (38%) and 5 (3%) had a higher preference of sweet taste, irrespective of acidity and firmness. Cluster 5, besides being a very minor cluster scored

sweet taste slightly lower compared to cluster 2 consumers. Cluster 6 was made up of 6% of consumers who preferred sweet tasting cultivars but disliked firm and acidic cultivars. The remaining 32% consumers were in clusters 3 (10%) and 4 (22%) and they had predilection for firm, crispy, juicy, acidic and moderately sweet cultivars. However, consumers in cluster 3 gave slightly lower preference scores compared to consumers in cluster 4. When applying Ward's clustering analysis to preference data of consumers of Western Cape Province, South Africa, Van der Merwe (2013) identified three distinct eating clusters. Eating cluster 1 (34% of total consumers), constituting mainly white and the youngest consumers (18-25) liked firm cultivars, tolerated sourness but disliked sweet taste and mealiness. Eating cluster 2 (22% of total consumers), which had an overrepresentation of white and 26-35 age group consumers, had a predilection for sour taste and apple flavour. Eating cluster 3 (44% of total consumers) with an overrepresentation of black and oldest (36+) consumers disliked sour taste.

In summary, studies that focused on clustering various apple consumers identified between two and six eating clusters depending on origin of consumers as well as the methodology used. Generally, there is a high representation of consumer groups that prefer crisp, hard and sour apples, but dislike mealiness. However, in South Africa specifically the largest consumer group in the Western Cape Province of South Africa disliked sour taste. Difference between studies can generally be attributed to the characteristics of the material assessed (e.g., assessing consumer preference for mealiness would require some of the samples to be mealy), the consumers who participated in the study (origin, age, gender, etc.) and maybe also differences in methodology (some studies do not assess starchy taste and grassy aroma while some other studies might have).

Apple ripening and consumer preference

Changes in internal and external characteristics of apples during ripening

Ripening involves the collective activities that take place during the final phases of growth and development through to the initial stages of senescence, characterised by changes in internal and external colour as well as taste and texture attributes (Kader, 1999). Apple, being a climacteric fruit, tends to undergo a rise in autocatalytic ethylene production during ripening, which initiates changes such as increased respiration rate, a rise in aroma production and softening of the flesh (Schaffer *et al*., 2007). Apples of the same cultivar but

differing in maturity and ripeness, present the consumer with products that differs vastly in terms of eating quality and appearance. Unripe apples are usually hard, sour, starchy, astringent, bitter and with green ground colour, while riper fruits are generally soft, sweet, less astringent and with yellow ground colour (Jaeger *et al*., 1998; Richardson-Harman *et al*., 1998). During ripening, apples and other fruits may decrease in some negative eating quality attributes such as hardness, bitterness, astringency and excessive sourness (Wills *et al*., 2007), increase in some positive eating quality attributes such as sweetness (Wills *et al*., 2007), and develop negative quality characteristics such as mealy textures with associated alcohol and off-flavours (Jaeger *et al*., 1998; Varela *et al*., 2005).

Iglesias *et al*. (2008) indicated that riper fruit of 'Gala' apple had higher sugar content, associated positively with anthocyanin content but negatively with acid content. Since apple fruit soften to a final firmness of 35 to 50 N, depending on cultivar (Bourne, 1979; Johnston *et al*., 2001), ripening has a significant influence on sensory texture attributes such as crispness, hardness and toughness (Abbott *et al*., 1984). Apple texture quality generally declines with increasing shelf-life duration with mealiness, as well as over-ripe and alcoholic flavour, gradually increasing (Varela *et al*., 2005). Although apples are generally prone to the development of mealiness during ripening (Jaeger *et al*., 1998; Andani *et al*., 2001), some cultivars such as Golden Delicious, Royal Gala and Topred are more susceptible than others such as Granny Smith and Fuji. Jaeger *et al*. (1998) and Varela *et al*. (2005) showed that mealiness associated positively with off-flavours, overripe fermented flavour, alcoholic flavour and odour. Mealiness also associated positively with total soluble solids and titratable acidity ratio but negatively with apple flavour (Jaeger *et al*., 1998), juiciness, sour taste and hardness (Harker *et al*., 2002a, Bonany *et al*. 2014).

During ripening, certain visible external changes that occur include peel colour change from green through to yellow, increase in blush coverage, as well as amount of greasiness on the peel (Lau, 1988; Kingston, 1992). These changes are due to loss of chlorophyll, accumulation of anthocyanins and accumulation and/or unmasking of carotenoids (Steyn, 2012). However, due to certain pre- and postharvest treatments, a softening in fruit texture as ripening occurs may not necessarily initiate an external peel colour change (Abbott, 1999). Factors such as stage of maturity (Harker *et al*., 1997, Richardson-Harman *et al*., 1998, Steyn, 2012),

ripeness level (Richardson-Harman *et al*., 1998, Steyn, 2012), cold storage conditions and duration (Harker *et al*., 1997, Soliva-Fortuny *et al*., 2002; Varela *et al*., 2005), as well as the sell-by date at point of sale (Harker *et al*., 1997) may all impact both the internal and external qualities of apple fruit.

Influence of ripening-related changes on consumer preference

Consumer preference generally increases as fruit change from unripe to ripe owing to the increased palatability associated with ripe fruits (Wills *et al*., 2007). Ripening-related changes such as yellowing of background colour, decrease in sour taste, apple flavour and firmness-related attributes as well as increase in overripe fermented flavour, TSS/TA ratio and mealiness tend to influence consumers' preference for apple quality substantially (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Richardson-Harman *et al*., 1998; Varela *et al*., 2005). Consumers generally tend to associate positively with attributes such as crispness, hardness, juiciness, high apple flavour, sweetness and moderate sour taste (Bonany *et al*., 2013; Van der Merwe, 2013). Attributes such as softness, mealiness and overripe fermented flavour influence consumers' preference negatively (Daillant-Spinnler *et al*., 1996; Jaeger *et al*. 1998; Varela *et al*., 2005). Harker *et al*. (2008) indicated that although fruit firmness correlates positively with consumers' preference for apple quality, some consumers like softer apples. There is thus a tendency that some consumer groups either tolerate or prefer softness and mealiness (Carbonell *et al*., 2008; Seppä *et al*., 2013; Van der Merwe, 2013). However, the extent to which consumers of different ethnic and age groups differ in relation ripeness level in apple fruit has not been determined.

Consumers usually evaluate fruit quality primarily via visual cues that provide information on acceptability (Steyn, 2012). External colour can provide an indication of freshness, ripeness, eating quality and cultivar (Richardson-Harman *et al*., 1998, Steyn, 2012). Fruit peel background colour changes from green to yellow due to chlorophyll breakdown is perceived to be a reliable indicator of ripening and eating quality (Wills *et al*., 2007). However, the association between peel colour and level of maturity, as well as fruit taste is sometimes unreliable (Steyn, 2012). Although a change in peel colour from green to yellow depicts ripeness, red fruits may not necessarily be considered as being ripe (Steyn, 2009) and it is often difficult to determine ripeness in red fruits especially full red types due to masking of

changes in background colour by overlaying anthocyanins. Harker and Hallett (1992) found that consumers classified 'Braeburn' apples with green background colour as less mature, while fruit with yellow background colour were considered more mature and ripe. Richardson-Harman *et al*. (1998) also showed that consumers associated a decrease in green ground colour and an increase in red blush coverage with ripeness level in 'Gala' apples. However, background colour was a better indicator of ripening than blush coverage.

Red colour is often perceived to indicate sweetness, while green colour is associated with sour taste and immaturity or unripeness of fruit (Clydesdale, 1993; Steyn, 2012). Van der Merwe (2013) showed that the eating quality preference of black and coloured consumers of the Western Cape Province of South Africa was driven by sweet taste and a tolerance for mealiness, often associated with riper/mealy apples and a dislike for sourness, which associated with green, unripe apples. The predilection of black and coloured consumers for sweet taste was apparent in their appearance preference of full and striped red peel colours (Van der Merwe, 2013). Coloured South African consumers also had higher appearance preference for fruit with yellow compared to green ground colour. As described above, a yellower ground colour is associated with ripeness and such fruit are expected to be sweeter, and if overripe, also soft or mealy (Lau, 1988; Kingston, 1992; Richardson-Harman *et al*., 1998; Van der Merwe, 2013).

Conclusions

Consumers generally segment into groups that either prefer hard, sour apples but dislike mealiness or groups that have a predilection for sweet taste, tolerate soft/mealy textures but an aversion for sour taste (Carbonell *et al*., 2008, Van der Merwe, 2013). However, consumers in different regions within a country or in different countries as well as different gender, ethnic and age groups within same region tend to differ in their apple quality preferences (Cliff *et al*., 2002; Bonany *et al*., 2013; Van der Merwe, 2013). Marketers and distributors could increase apple sales and profitability in South Africa by targeting specific cultivars with desired quality characteristics at particular consumer groups based on their preference patterns (Harker, 2001). However, previous studies that focused on determining South Africa's consumers' preference of apple quality was based on only consumers in the Western Cape Province (Van der Merwe, 2013). Therefore, in order to develop effective

marketing programmes and ensure consumers' satisfaction throughout South Africa as a whole, there is the need to determine the drivers of preference for consumer groups in other metropolitan regions. Since ripening related changes in eating quality and appearance attributes have such a great influence on consumer preference, it would also be beneficial to determine the preference of South African consumers for apples of different ripeness levels. It is perceivable that different ethnic groups in South Africa may differ in their tolerance of certain ripening related, negative drivers of liking, such as mealiness.

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PAPER 1: DRIVERS OF PREFERENCE FOR APPLE EATING QUALITY AND APPEARANCE AMONG SOUTH AFRICAN CONSUMERS OF DIFFERENT ETHNIC AND AGE GROUPS

Abstract

The attributes that drive South African consumer preference for apple eating quality and appearance were investigated in this study. Black, white and Indian consumers of two age groups (18-25 or 26+) and different socio-economic background participated in consumer studies conducted in Pretoria, Gauteng province and Durban, Kwa-Zulu Natal province. Nine different commercial apple cultivars were used to attain variation in eating quality and appearance attributes. Descriptive sensory analysis was carried out on all nine cultivars using a trained panel. Consumer preference for eating quality and appearance of all nine cultivars was assessed on a 9-point hedonic scale. Principal component analysis (PCA) was used to project the outcome of descriptive sensory analysis onto consumers' preference dimension. Region, ethnic and age groups as well as gender, interacted for consumer preference of eating quality. Black consumers from both Gauteng and Kwa-Zulu Natal and from both age groups (18-25 and 26+), as well as white and Indian consumers from the older age group (26+) had a high preference for sweet taste. White and Indian consumers from the young age group (18-25) preferred cultivars that were crisp and firm. The male consumers' eating quality preference associated positively with sweetness. Age, as well as region, ethnic group and gender interacted for consumer preference of appearance. The older (26+) consumers disliked the appearance of 'Granny Smith', 'Braeburn' and also, to a lesser extent, 'Fuji'. Younger (18-25) consumers disliked the appearance of 'Braeburn' and 'Fuji' but preferred the appearance of 'Granny Smith'. Black consumers generally preferred the appearance of 'Golden Delicious'. Since 'Golden Delicious' associated with sweet taste, black consumers' appearance preference associated with their eating quality preference. White and Indian consumers preferred the appearance of 'Granny Smith' which closely associated with sour taste and also with their eating quality preference. Our results indicate that specific apple cultivars could be targeted to specific ethnic groups to increase sales.

Keywords *Malus x domestica* (Borkh.), attributes, consumer preference, principal component analysis.

Introduction

Apple (*Malus x domestica* Borkh.) exports to the United Kingdom, which was South Africa's largest export destination, has rapidly declined from 37% (2009) to 21% (2014) (HORTGRO, 2014) as a result of increased market barriers driven by food retail sector requirements, slow economic recovery, as well as intense competition from other Southern Hemisphere countries for traditional export markets in Europe (GAIN Report, 2012). Notwithstanding this decline in apple exports to the United Kingdom, South Africa's domestic fresh fruit market continues to grow (GAIN Report, 2012), with 27% of the crop produced sold locally (HORTGRO, 2015). South Africa's market growth at both the wholesale and retail level is as a result of a rapidly growing middle class (SAARF, 2012), and also a preference for fresh fruit over canned by consumers in the middle to upper income brackets (GAIN Report, 2012). The local market apple consumer becomes a potential target whose preference for apple quality must be understood in order to boost apple sales substantially. Therefore, evaluating the attributes that drive the local consumers' preference for apple eating quality and appearance will enhance apple sales locally considering the fact that the local market forms a large proportion of the total sales and provides a buffer to fluctuations in export market demand.

A local study carried out in the Stellenbosch area, Western Cape, South Africa in relation to ethnic and age group effects on consumer preference for apple quality, indicated that flavour attributes such as sweet taste were important drivers of liking for black and coloured consumers (Van der Merwe, 2013). These consumers disliked sour taste and differed from white consumers who gave higher preference scores for firm and sour cultivars. Black and coloured consumers liked the appearance of full and striped red apples and this is in close association with their preference for sweet taste. However, black and coloured consumers disliked the appearance of 'Granny Smith', with this cultivar also closely associating with sour taste. White consumers preferred the appearance of firmer fruit such as 'Pink Lady'® and 'Granny Smith', which associated closely with their preference for sour taste and firm texture. The youngest consumers (18-25 years) had a higher preference for sour taste and firmness. The eating quality preference of the older consumers (36+ years) associated strongly with sweet taste. The appearance preference of all age groups, however, did not correlate with their eating quality preference (Van der Merwe, 2013). These findings notwithstanding, information on the attributes that drive consumers' of other Metropolitan regions of South Africa preference for apple eating quality and appearance is still limited.

Also, there is no indication that the preference patterns of black, coloured and white consumers of the Western Cape region will apply to the rest of the country. South Africa's population is approximately 52.98 million, made up of 79.2% black, 8.9% white, 8.9% coloured, 2.5% Indian/Asian and 0.5% other ethnic groups (STATSSA, 2013) of varying socioeconomic backgrounds (Viljoen and Gericke, 2001a) whose food preference patterns are likely to differ (Hillman, 1979). Even though the effect of ethnic group on food preference is not clearly understood (Pangborn *et al*., 1988), food choice and consumption is influenced substantially by cultural factors (Prescott and Bell, 1995; Rozin, 1996). What is more, South Africa is made up of nine different provinces with each province characterized by consumers of varying ethnic and age groups. Gauteng Province, being the most populated with 12.7 million people (24% of the total population) (STATSSA, 2013) is made up of 74% black, 20% white, 4% coloured and 2% Indian/Asian (South Africa info, 2012). Kwa-Zulu Natal Province, the second most populated with 10.5 million people (19.7% of the total population) (STATSSA, 2013) is made up of 85% black, 9% Indian/Asian, 5% white and 1% coloured consumers (South Africa info, 2012). This study therefore evaluated the attributes that drive the preference of black, white and Indian consumers of two varying age groups [(young (18-25); older (26+)] in the Gauteng and Kwa-Zulu Natal provinces for apple eating quality and appearance. The younger (18-25) group constituted 66% of the total consumers studied, while the older group (26+) comprised 6.4% (26-30), 13.0% (31-40), 9.0% (41-50), 4.6% (51-60) and 1.0% (61+).

Studies on apple preference in relation to either liking for different apple cultivars or determining the attributes that drive consumer preference for apple quality have been conducted in the United Kingdom, Denmark, Holland, Germany, Switzerland, Poland, France, other European countries and the Western Cape region of South Africa (Mante, 1973; Van de Abeele and Reijnders, 1980; Ellinger, 1987; Barendsee, 1993; Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Höhn and Güggenbühl, 1999; Kellerhals *et al*., 1999; Konopacka *et al*., 2006; Tomala *et al*., 2009; Van der Merwe, 2013). European apple consumers' preference for apple eating quality is driven by taste and textural attributes such as sweet taste, moderate sour taste, high apple flavour, crispness, crunchiness and juiciness, but they dislike mealiness and a strongly acidic taste (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Andani *et al*., 2001; Bonany *et al*., 2014). A European consumer study involving 4290 consumers in seven different countries indicated a strong interaction between country

and cultivar. All the countries with the exception of Germany preferred sweet tasting apples with medium or low acidity and high firmness. Consumers in Germany, and to an extent also those in the Netherlands and Switzerland, preferred cultivars with a high level of acidity (Bonany *et al*., 2013).

Appearance, particularly peel colour, is considered one of the most important factors that influence consumer preference for apple quality and fruit sales (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002). Consumers' perception of fruit quality, especially in relation to fruit taste, as well as their decision to buy an apple, is largely influenced by fruit colour (Jaeger and MacFie, 2001; Shankar *et al.*, 2010; Steyn, 2012). Although, different groups or segments of consumers are expected to differ in what they consider as acceptable in relation to fruit appearance (Gamble *et al*., 2006), there is limited information on consumers' preference for apple appearance. Fischer and Fischer (2008) found that appearance attributes are major drivers of liking and that European consumers prefer bi-coloured fruit with an attractive shiny red over-colour. Cliff *et al*. (2002) found that New Zealand consumers prefer striped apples; consumers in Nova Scotia, Canada prefer blushed apples, while consumers in British Columbia, Canada are more accepting of a range of apple types.

Racskó *et al.* (2009a, b) reported that consumer preference for apple attributes and eating quality was influenced by age-related differences even though Jaeger *et al.* (1998) and Hampson *et al.* (2000) found no effect of age on apple preference scores. According to Van der Merwe (2013), young (18-25) Stellenbosch consumers preferred firm, sour cultivars, while older (36+) consumers preferred cultivars that were associated with sweet taste. Similarly the latter consumers' appearance preferences associated with their preference for eating quality.

In view of the above, the aims of this research were to: 1) Determine if region, ethnic group and age significantly affect consumers' preferences for apple eating quality and appearance, and 2) establish the main drivers of liking for black, white and Indian consumers and for consumers from two different age groups.

Materials and methods

Plant material

Nine apple (*Malus* x *domestica* Borkh.) cultivars namely, Braeburn (BB), Cripps' Pink, Cripps' Red, Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), and Topred (TR) were used in this study. These cultivars were chosen to attain a variety in flavour and textural attributes, as well as colour and colouring patterns. The trademark name reserved for 'Cripps' Pink' fruit with more than 40% blush is Pink Lady® (PL), while Joya™ (JY) is the trademark name given to 'Cripps' Red' apples. The 'Cripps Pink' and 'Cripps' Red' apples that were used in this study met the required quality standards and will therefore be referred to by their trademark names. All nine cultivars were of first grade export quality. 'BB', 'GD', 'GS', 'PL', 'RG' and 'JY' were obtained from Colors Fruits, Novo Pack House, Paarl. 'FU' and 'TR' were obtained from Valley Parkers Co-op Ltd, Valley Road, Grabouw and 'HC' from Dutoit Agri, Ceres. All fruit were stored at -0.5°C at the Department of Horticultural Science, Stellenbosch University, South Africa, until assessment.

Descriptive sensory analysis

Descriptive sensory analysis (DSA), of the samples was carried out using a panel. The DSA panel consisted of 8 female judges with prior experience in apple testing. The judges were trained using the consensus method and analyses were performed according to the 'Generic Descriptive Analysis' (Lawless and Heymann, 2010). Four training sessions were carried out on 30 and 31 July 2012 with two sessions per day using all nine cultivars. Judges were tested for consistency using PanelCheck (Nofima, Norway) and samples of all nine cultivars were used to calibrate the panel on the sensory attributes associated with the cultivars to be tested. Unstructured line scales were used for attribute intensity analysis. The left hand side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity. The judges came to a consensus on a list of attributes for describing the flavour and texture of peeled samples for the attributes, sweet taste, sour taste, apple flavour, crispness, hardness, crunchiness, juiciness, mealiness and sponginess. Judges also agreed to analyse samples for astringency, bitterness, and toughness of peel of unpeeled samples (Table 1).

Evaluation of samples were carried out on 2 and 3 August 2012 for all nine cultivars. One fruit, cut lengthwise, was equally shared between the judges such that each panel member received an eighth of an apple; thus all 8 judges received the same apple. Each treatment was replicated four times with two replicates per day. Each sample was coded with a three-digit random code and slices of unpeeled fruit were presented in petri dishes (Kimix, South Africa). Presentation of samples was done in a complete randomised design, balanced to minimize order and carry over effects (MacFie *et al*., 1989). The latter design was based on the Williams Design presented by Compusense® Five data collection software that collected data electronically (Version 4.2, Compusense Inc., Guelph, Ontario, Canada). Judges were seated in individual tasting booths with computers and standardised artificial daylight lighting and at a room temperature of 21 °C. Distilled water and unsalted fat free biscuits (Woolworths, South Africa) were provided as palate cleansers between samples.

Instrumental measurements

There were a total of nine treatments representing the nine apple cultivars and each treatment was replicated three times with three fruit per replicate. The three fruit per replicate were analysed together as a replication set. The fruit were removed from cold storage and allowed to attain room temperature before instrumental analyses commenced.

Flesh firmness (N) was measured using a penetrometer (Fruit Texture Analyser, GUSS Manufacturing (Pyt) Ltd., Strand, South Africa) fitted with an 11 mm diameter probe. Two readings were taken on opposite peeled sides of the fruit approximately halfway between the calyx and the stem ends. Slices of apple were placed in a juice extractor and the juice was used to determine the total soluble solids (TSS) concentration and the titratable acidity (TA). TSS was measured using a calibrated hand-held refractometer (TSS 0-32%, Model N1, Atago, Tokyo, Japan). TA was measured using an automated titrator (Tritino 719S and Sample Changer 674, Metrohm Ltd., Herisau, Switzerland) by titrating 5 g of juice from each apple sample with 0.1 M NaOH to a pH of 8.2. The TA is expressed as percentage malic acid. The hue angle of each apple on shaded and blushed side respectively, was measured using a colorimeter (Konica CR-400, Minolta Co. Ltd., Tokyo, Japan). Percentage dry matter concentration (DMC) was determined by weighing a fresh sample of fruit and oven drying the fruit over a period of 48 h at 75 ºC. Samples were weighed immediately and returned into

the oven for a further 48 h and re-weighed after every 24 h to ensure all the moisture had evaporated. DMC was determined as dry weight as a percentage of fresh weight.

Consumer analysis

Consumer recruitment

Consumer preference assessments on the nine apple cultivars were carried out in the sensory research laboratory of the Department of Food Science, University of Pretoria and in a lecture room of the Department of Food and Nutrition: Consumer Sciences, Durban University of Technology. The assessments in Pretoria were conducted on 14 and 15 August while those in Durban were conducted on 23 and 24 August 2012. Two hundred and ninety black and white consumers and 289 black and Indian consumers within the young (18-25 years) and older (26+ years), age groups were recruited in Pretoria and Durban, respectively. The older age group (26+) ranged from 26 to 61, but a majority of these consumers were found in ages 26 to 41.

The total of 579 consumers recruited were asked to complete a structured questionnaire that consisted of four sections (Q1-Q4). Socio-demographic information collected in section 1 (Q1) (Appendix 2) included gender, age, ethnic group, education and current employment. Assessment of preference for actual eating quality and appearance were done in sections 2 and 3 (Q2 and Q3) (Appendix 3-6), respectively. General information on consumers' conceptual preferences for apple taste and texture attributes, as well as factors that influence their apple purchase patterns were collected in section 4 (Q4) (Appendix 7). Information on consumers' conceptual preference for apple peel colour and colouring patterns were also collected in section 4 (Q4) (Appendix 8), as well as their familiarity with and conceptual preference for the nine different apple cultivars section 4 (Q4) (Appendix 9) used in the study.

Preference for eating quality

Unpeeled samples of all nine cultivars, coded with a three-digit random code, were presented to consumers in open petri dishes on white trays in a completely randomised block design, and balanced for order and carry-over effects. A sample consisted of an eighth of an apple, sliced from stem end to calyx end. Thus, every eight consumers received a sample set of the

exact same fruit, while the next set of eight consumers received different fruit from the same cultivars. In the actual eating quality assessment, consumers were asked to taste the fruit and to indicate, using a nine-point hedonic scale, which term best described how they perceived each apple sample they tasted. The nine point hedonic scale ranges from 1 – *dislike extremely*; 5 – *neither like nor dislike* and 9 – *like extremely* (Lawless and Heymann, 2010). Distilled water was available for consumers to clean their palate between samples. A room temperature of 21 °C was maintained throughout the tasting.

Preference for appearance

Consumers were presented with life-size photographs of all nine apple cultivars (Fig. 1) analysed in the eating quality test. Photographs were taken on 2 August 2012. Section 3 (Q3), comprising three pages of the structured questionnaire, contained all nine photographs with three photographs per page. Consumers analysed all nine photographs in a completely randomised block design. Three sets (1, 2 & 3) were created to ensure that photographs were presented to consumers in varying order to minimize order effect. The photograph order was identical within sets but was randomised between sets. Photographs were assigned three-digit random codes, which were again randomised between sets but identical within sets. Every 10 judges received the same set of photographs.

Conceptual preference and purchase factors

Consumers' preference for certain apple sensory attributes, as well as some important aspects considered when buying or eating an apple were assessed in section 4 (Q4) of the structured questionnaire. Their degree of liking for varying apple peel appearances, as well as their preference for the apple cultivars presented in sections 2 (Q2) and 3 (Q3) were also tested. Consumers indicated their degree of liking for apple sensory attributes, apple peel appearances and apple cultivars respectively on the nine-point hedonic scale and also rated the factors they considered important when buying or eating apples on a structured nine-point scale.

Statistical procedures

The purpose of the study was to analyse the interaction between region, ethnic and age group of consumers and their preference for apple attributes relating to eating quality and

appearance. Furthermore, the effects of additional factors (i.e. gender, education, employment status etc.) that contribute significantly to the intrinsic (i.e. eating quality and appearance) and extrinsic (i.e. price, cultivar indication on the packaging, etc.) drivers of consumer liking were also analysed. Instrumental and sensory data were included in this study to serve as an external data set to further explain the intrinsic factors that drive consumers' apple preferences.

The sensory data for each attribute were subjected to a three factor analysis of variance (ANOVA) using cultivars, 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 samples' sensory attributes. Cultivar attributes were therefore averaged across replicates and panellists. Instrumental data for TSS, TA, TSS/TA, firmness and DMC were subjected to one-way analysis of variance, with cultivar as main effect.

In order to compare the consumer characteristics that contributed to consumers' preference for the nine apple cultivars, these characteristics were subjected to a 9 x 4 x 2 x 2 x 3 x 5 factorial ANOVA, with factors cultivar, region ethnic group (Gauteng black, Gauteng white, Kwa-Zulu Natal black and Kwa-Zulu Natal Indian), age group [(young (18-25), older (26+)], gender (male and female), education [(lower than final school year Grade 11 or below), final school year (Grade 12 or matric) and tertiary education)] and employment (student, assistant, administrative, professional and other). SAS statistical software (SAS, version 9, 1999, Cary, North Carolina, USA) was used for the analyses. Statistical significance was defined at $P\leq0.05$. Non-significant main factors and interaction factors were removed from the model, and a 9 x 4 x 2 x 2 ANOVA was redone with factors cultivar, region ethnic group, age group and gender. This four-factor ANOVA model was also applied to the analyses of appearance preference and conceptual preference, where consumer liking for actual apple appearance and conceptually tested cultivars and attributes were taken as the dependent variables. Student's t-LSD's (Least Significant Difference) were calculated at a 5% significance level and used to determine whether preference for eating quality and appearance differed significantly between different gender, age and region ethnic groups.

Principal component analysis (PCA) was performed in order to study the data structure and the association between the sensory attributes and consumer characteristics (gender, age and region ethnic group) that contributed significantly to consumer preference. In order to reduce variation and the number of points on the corresponding figures, mean values of the liking scores were calculated for combinations of region ethnic_group*cultivar, age_group*cultivar and gender*cultivar. These means, together with the sensory means and the corresponding number of observations, were taken as input to a weighed PCA of the correlation matrix. Means for region ethnic_group*cultivar, age_group*cultivar and gender*cultivar were projected onto separate PCA spaces. To measure the linear relationship between the sensory attributes and consumer liking, Pearson's correlation coefficients were calculated for each of the different age and region, ethnic groups (Pèneau *et al.*, 2006). A similar PCA was performed in order to study the effect of region, ethnic group, age group and gender on consumers' preference for apple appearance. Lastly, partial least squares regression (PLS) was conducted to extract the main patterns of relationship between the instrumental and sensory data tables, X and Y. respectively. All multivariate analyses were conducted using XLStat (Addinsoft, Version 2013.5.07, New York, USA).

Results

In order to ensure clarity in reporting this part of the study, "preference for eating quality" indicates a consumer's degree of liking for the overall texture and flavour of apples, where the term "flavour" includes sweet taste, sour taste and the aroma volatiles (Rowan *et al.*, 2009). "Preference for appearance" indicates how consumers liked the overall colour and shape of the fruit.

Consumers tasted all apple samples to give an indication of "preference for eating quality" and viewed life-size colour photographs of representative apples to indicate "preference for appearance", which will be referred to as "actual evaluation". Preference for specific aspects of eating quality (e.g. crispness, crunchiness, juiciness etc.), colour and colouring patterns (e.g. green full, pink blush, red bi-colour, etc.) was also evaluated conceptually, but reporting in this Chapter will only focus on consumers actual liking for eating quality and appearance. Conceptual factors that impact on consumers' preference for apple quality will be reported on in Paper 2.

Sample attributes

For the sake of readability and brevity, only the most prominent differences in sensory and instrumental sample attributes will be reported here.

Instrumental measurements

'TR' had the highest mean TSS, but not significantly higher than 'PL', 'FU', 'HC', 'JY' and 'GD' (Table 2). 'GS' had the lowest TSS, but not significantly lower than 'BB'. 'GS' had the highest mean TA value and was significantly higher than all cultivars except for 'BB', 'PL' and 'JY'. 'FU' had the lowest TA value, but was not significantly lower than 'TR' and 'RG'. TSS/TA ratios for 'FU' and 'TR' were significantly higher than all the other cultivars. 'GS' had the lowest mean TSS/TA ratio, but was not significantly lower than 'BB', 'PL' and 'JY'. Although 'JY' had the highest mean score for firmness, it was not significantly firmer than 'PL', 'BB', 'HC', 'GS' and 'FU'. 'GD' had the lowest score for firmness, but it was not significantly lower than 'RG' and 'TR'. 'JY' had the highest mean for DMC, but not significantly higher than 'PL' and 'TR'. 'GD' had the lowest mean score for DMC, but not significantly lower than 'GS', 'RG', 'BB' and 'FU'.

Sensory profiles

'TR' and 'FU' had the highest mean sweetness, but were not significantly sweeter than 'GD' and 'PL'. 'GS' had the lowest mean sweetness and was significantly less sweet and also more sour than all other cultivars (Fig. 2). 'FU' and 'TR' had the lowest sourness values, but not significantly lower than 'RG' and 'GD'. 'PL' had the highest mean score for apple flavour, but not significantly higher than 'TR', 'JY' and 'GD'. 'RG', 'HC', 'FU' and 'GS' did not differ significantly from each other in terms of apple flavour. Astringency with peel scores were very low (<5) and cultivars did not differ significantly for this attribute. 'TR' was perceived as significantly more bitter than other cultivars when tested with peel, but all bitterness scores were <10. The other cultivars did not differ significantly from each other in terms of bitterness with peel.

'HC' was perceived as the crispiest, hardest and crunchiest cultivar, although it was not crispier than 'GS' (Fig. 3). 'GD' and 'RG' were perceived as the least crisp, hard and crunchy cultivars. 'RG' was the mealiest cultivar, but with a low mean mealiness score of 6.6

(Fig. 3). ‘GD’ (3.2) and ‘TR’ (2.7) did not differ from each other in terms of mealiness. The other cultivars all scored zero for mealiness and were thus perceived as non-mealy. ‘PL’ and ‘FU’ were perceived as the juiciest cultivars, but were not significantly juicier than ‘BB’, ‘GS’ and ‘HC’. ‘RG’ was significantly the least juicy cultivar. ‘GD’ was the spongiest cultivar, but scores for this attribute were low (<10). ‘GS’ had the highest mean value for peel toughness, but was not significantly tougher than ‘TR’. ‘RG’ and ‘GD’ had the least tough peel.

Correlation analysis of sensory and instrumental attributes

The Pearson correlation matrix among all variables can be observed in Table 3. A number of important significant correlations were found amongst the sensory and instrumental variables. Among the instrumental variables, firmness and TA were significantly correlated (r=0.72). The relationships between instrumental quality variables (TA, TSS, TSS/TA) and their corresponding sensory variables, sour taste, sweet taste, as well as the relationship between firmness and its corresponding variables, crispness, crunchiness and hardness were also significant. The TA and sour taste correlation was the highest with an r-value of 0.97. TA correlated negatively with sweet taste (r=–0.70). Sour taste also correlated negatively with TSS (r=–0.71) and TSS/TA (r=–0.93).

The sensory variables show some degree of correlation, i.e. the flavour, mouthfeel and textural attributes. Sweet taste correlated significantly with sponginess (r=0.79), but correlated negatively with sour taste (r=–0.79). Sour taste correlated significantly with crispness (r=0.71), crunchiness (r=0.69) and hardness (r=0.73) but correlated negatively with sponginess (r=–0.86). Astringency correlated significantly with bitterness (r=0.77) and peel toughness (r=0.78). Peel toughness correlated significantly with crispness (r=0.73), crunchiness (r=0.68) and hardness (r=0.76). Crispness correlated significantly with crunchiness (r=0.99), hardness (r=0.98) and juiciness (r=0.77). Crispness correlated negatively with mealiness (r=–0.89) and sponginess (r=–0.80). Crunchiness correlated significantly with hardness (r=0.98) and juiciness (r=0.75) but negatively with mealiness (r=–0.87) and sponginess (r=–0.78). Similarly, hardness correlated negatively with mealiness (r=–0.83) and sponginess (r=–0.83). Juiciness also correlated negatively with mealiness (r=–0.90).

To ascertain the overall association between sensory attributes and instrumental measurements of apple fruit from the nine cultivars used for the study, principal component analysis (PCA) and partial least squares regression (PLS) were conducted (Figs. 4 & 5). According to the PCA bi-plot (Fig. 4), the first and second principal components (PC 1 and PC 2) accounted for 48.6% and 20.5% of the variability in cultivar attributes, respectively. According to PC 1 of the PCA bi-plot (Fig. 4) and dimension 1 of the PLS plot (Fig. 5), the sensory attributes mealiness and sponginess associated with 'FU', 'GD' and 'RG'. Both TSS/TA and TSS, as well as sweet taste associated with 'TR' and 'FU, whereas 'TR' shows a strong association with the basic taste modality of bitterness. When viewing both multivariate plots, it is furthermore clear that astringency with peel is not well associated with any of the apple treatments, most probably because the mean intensity of this attribute was extremely low, i.e. well below 5 when measured on a 100-point intensity scale. The attributes sour taste and TA associated strongly with 'GS' and 'BB', whereas instrumental firmness, DMC and apple flavour associated with both 'JY' and 'PL'. The textural sensory attributes (juiciness, crispness, hardness and crunchiness, as well as toughness with peel) seem to associate with the cultivars on the right side of PC 1 of the PCA bi-plot (Fig. 4) and the left side of dimension 1 of the PLS plot (Fig. 5).

Consumer characteristics

The total consumer group (n=579), comprised 29% black and 22% white consumers in Gauteng Province, as well as 34% black and 15% Indian consumers in Kwa-Zulu Natal Province (Table 4). Sixty-six percent of the consumers were aged between 18 and 25 (young age group) and 34% were 26 years or older (older age group). Kwa-Zulu Natal Indian consumers in the older age group were underrepresented. Gauteng white male consumers, as well as Kwa-Zulu Natal Indian male and female consumers were also underrepresented. Sixty-four percent of the consumers had tertiary education, 31% had matric and 5% had grade 11 or below. Gauteng white and Kwa-Zulu Natal Indian consumers with education level of grade 11 or below were not represented. Kwa-Zulu Natal Indian consumers with matric and Gauteng black with grade 11 or below were underrepresented. Consumers' employment status representation showed 68% percent were students, 10% were professionals, 9% had other forms of employment than what was listed, 8% were in administrative positions and 5% were assistants. Gauteng white and Kwa-Zulu Natal Indian consumers with other forms of employment than the listed were not represented. Sixty-three

percent of the consumers buy fruit once a month or less frequently, but 72% buy an apple once a month or less frequently. Although 72% of consumers purchase apple less frequently (once a month), 57% of consumers eat apples more frequently (2 to 3 times a week) (Table 4).

Eighty-four percent of the total group of consumers (n=579) are familiar with 'GD', 77% are familiar with 'GS' and the least known cultivar is 'BB' (26%) (Table 5). Even though Gauteng black and white consumers, as well as Kwa-Zulu Natal black and Indian consumers are most familiar with 'GD' and 'GS' apples, higher percentages of black consumers in Gauteng and Kwa-Zulu Natal are more familiar with 'GD'. Gauteng white and Kwa-Zulu Natal Indian consumers are more familiar with 'GS'. Eighty-one percent of Gauteng black consumers are most familiar with 'GD', 92% of Gauteng white consumers are most familiar with 'GS', 88% of Kwa-Zulu Natal black consumers are familiar with 'GD' and 83% of Kwa-Zulu Natal Indian consumers are most familiar with 'GS'. Consumers' familiarity with 'HC', a cultivar not available in South Africa, indicated 46% Gauteng black, 33% Gauteng white, 50% Kwa-Zulu Natal black and 39% Kwa-Zulu Natal Indian are familiar with this cultivar. The least known cultivar by black, white and Indian consumers in Gauteng and Kwa-Zulu Natal is 'BB', although the familiarity score for 'HC' in South Africa should be 0% for all consumer groups.

The older age group (26+) is more familiar with most of the cultivars presented in the study than the young age group (18-25) (Table 5). The cultivar familiarity sequence for the young age group (18-25) show 82% familiarity with 'GD', 76% with 'GS', 47% with 'PL', and 46% with both 'TR' and 'HC'. The older age group (26+) are also most familiar with 'GD' (88%), 'GS' (79%), 'RG' (57%), 'TR' (55%) and 'PL' (50%). Seventy-seven percent of male consumers are familiar with 'GD', 67% are familiar with 'GS', 46% with 'HC' and 44% each are familiar with 'RG' and 'TR', respectively. Female consumers are more familiar with apple cultivars presented than male consumers (Table 5). Female consumers are familiar with cultivars in the following sequence; 'GD' (89%), 'GS' (83%), 'PL' (54%), 'TR' (53%) and 'RG' (49%).

Consumers with a tertiary degree are more familiar with apple cultivars than consumers with Grade 12 (matric). Consumers with Grade 12 (matric) qualification were also more familiar with apple cultivars than those with a qualification of Grade 11 (standard 9) or below (Table 6). Eighty-four percent of consumers with tertiary qualification are familiar with 'GD, 76% are familiar with 'GS' and 27% are familiar with 'BB' which is their least known cultivar. Eighty-five percent of those with matric qualification are familiar with 'GD', with 83% being familiar with 'GS' and 22% familiar with 'BB' which is their least known cultivar as well. However, with the grade 11 or below group, although 81% of consumers are familiar with 'GD', only 48% are familiar with 'GS'. Twenty-three percent being the lowest percentage of the grade 11 or below group are familiar with 'BB'.

Consumers' familiarity with apple cultivars in relation to their employment status showed that 'GD' is the most familiar cultivar followed by 'GS' (Table 6). This trend notwithstanding, a higher percentage (96%) of the consumers in the administrative category is familiar with 'GS'. One hundred percent of consumers with assistant employment status are familiar with 'GD'. Although 95% of consumers with professional employment status are familiar with 'GD' and 92% are familiar with 'GS', 20% are familiar with 'JY' which is their least known cultivar.

Apple fruit purchase and consumption, respectively, for the nine apple cultivars used in the study follow similar trend as in familiarity with cultivars. The most frequently (≤3-5x week) purchased and consumed cultivar is 'GD', then 'GS' with the least purchased and consumed being 'BB' (Table 7).

Consumer groupings

There were significant two- and three-way factor interactions for both consumers' liking for eating quality, as well as consumers' preference for cultivar appearance. The factors *Region ethnic group* and *age group* interacted significantly with consumers' liking for *cultivar preference* (Table 8). *Gender* also interacted significantly with *consumers' cultivar preference* (Table 8). *Age* interacted significantly with *consumers' preference for cultivar appearance* (Table 9). The factor *Region ethnic group* and *gender* also interacted significantly with consumers' *preference for cultivar appearance* (Table 9).

Grouping based on region, ethnic, gender and age groups

Actual preference for eating quality

The actual preference for eating quality will be discussed according to the significant interactions provided in Table 8. The PCA bi-plot (Fig. 6) indicated the position of consumer preferences for eating quality obtained for the different regions, ethnic groups (Gauteng black, Gauteng white, Kwa-Zulu Natal black and Kwa-Zulu Natal Indian) and age groups [(young (18-25), older (26+)] in relation to sensory attributes of apple fruit from the nine cultivars. The first (PC 1) and second principal components (PC 2) accounted for 39.7% and 31.3% of the variability in the consumer responses, respectively. Young white Gauteng and young Indian Kwa-Zulu Natal consumers showed similar eating quality preferences (right side of PC 1) and were highly correlated (r=0.77; P=0.016), but differed from those of young black Gauteng, older black Gauteng, older white Gauteng, young black Kwa-Zulu Natal, older black Kwa-Zulu Natal and older Indian Kwa-Zulu Natal (left side of PC 1). The young black Gauteng and older white Gauteng consumers recorded the highest correlation at r=0.94 and P=0.0001.

In terms of the correlation between the preference for eating quality and the sensory attributes (Fig. 6), the young white Gauteng and young Indian Kwa-Zulu Natal consumers associated positively with crispness (r=0.81; P=0.009 for young white Gauteng, r=0.89; P=0.002 for young Indian Kwa-Zulu Natal consumers), crunchiness (r=0.84; P=0.005 for young white Gauteng, r=0.87; P=0.002 for young Indian Kwa-Zulu Natal consumers), hardness (r=0.74; P=0.024 for young white Gauteng, r=0.82; P=0.006 for young Indian Kwa-Zulu Natal consumers), juiciness (r=0.80; P=0.010 for young white Gauteng, r=0.81; P=0.009 for young Indian Kwa-Zulu Natal consumers). The young Indian Kwa-Zulu Natal consumers also associated reasonably strongly with peel toughness (r=0.73; P=0.027), whereas both the preference of young white Gauteng and young Indian Kwa-Zulu Natal consumers correlated negatively with mealiness (r=−0.80; P=0.010 for you□g white Gaute□g, r=−0.83; P=0.005 for young Indian Kwa-Zulu Natal consumers). In contrast, as indicated on the left side of PC 1 (Fig. 6), the preference of young black Gauteng, older black Gauteng, older white Gauteng, young black Kwa-Zulu Natal, older black Kwa-Zulu Natal and older Indian Kwa-Zulu Natal consumers associated positively with sweetness (r=0.67; P=0.048 for young black Gauteng, r=0.79; P=0.011 for older black Gauteng, r=0.69; P=0.039 for older white Gauteng, r=0.82; P=0.007 for young black Kwa-Zulu Natal, r=0.82; P=0.007 for older black Kwa-Zulu Natal

and r=0.74; P=0.024 for older Indian Kwa-Zulu Natal). The preference for eating quality scores of the older black Gauteng and older black Kwa-Zulu Natal consumers correlated negatively with sourness (r=−0.87; P=0.002 for older black Gauteng and r=−0.77; P=0.016 for older black Kwa-Zulu Natal).

As illustrated in Fig. 6, it is thus clear that the sensory attributes crispness, crunchiness, hardness, juiciness and mealiness can be regarded as the main drivers of liking for the young white Gauteng and young Indian Kwa-Zulu Natal consumers, whereas sweetness drives the preference for eating quality of all the black consumers in the respective age groups, as well as in both locations and also the older white Gauteng and older Indian Kwa-Zulu Natal consumers. Furthermore, sourness is a strong negative driver for the preference of the older black Gauteng and older black Kwa-Zulu Natal consumers.

As shown in Figs. 7a and b, the black consumers', as well as older white and Indian consumers' preference for sweetness was indicative of the high preference scores they gave for 'FU' and 'TR' which clearly associated with sweet taste (Fig. 5) and also had the highest TSS/TA ratio (Table 2). These consumers liked 'GS' the least, the cultivar which is highly associated with sour taste (Fig. 6). The young white Gauteng consumers' gave a high preference score for 'HC' which is crunchy, hard and firm, whereas the young Indian Kwa-Zulu Natal consumers' scored the firm and sour cultivars such as 'PL', 'HC' and 'GS' high for preference. The young Indian and young white also gave low preference scores for 'GD' and 'RG', which were the soft, mealy apples.

The interaction between gender and preference for eating quality was primarily driven by the significantly higher preference of male consumers for 'RG' and 'TR' (Fig. 8). The most preferred cultivar for both male and female consumers is 'FU' but the male consumers' preference for 'FU' was not significantly higher than their preference for 'TR'. Female consumers' preference for 'FU' was significantly higher than their preference for all the other cultivars. They preferred 'HC', 'PL' and 'TR' significantly more than 'BB', 'GD', 'RG' and 'GS'. Although 'GS' was preferred the least by both male and female consumers, the preference of female consumers' for 'GS' was not significantly lower than their preference for 'RG'.

Preference for appearance

Interaction effects for *region and ethnic group*, *gender* and *age* with actual *preference for cultivar appearance* are provided in Table 9. *Age*, *cultivar preference* and *preference for cultivar appearance* interacted significantly. According to the PCA bi-plot (Fig. 9), PC 1 and PC 2 account for 86.2% and 13.8%, respectively, of the variability in the appearance preference responses of consumers from the young (18-25) and older (26+) age groups. The appearance preference of the young and older consumers did not separate on PC 1 and grouped together with the appearance of 'HC', 'RG', 'TR', 'PL', 'GD' and 'JY', and opposite to 'GS', 'BB' and 'FU'. 'GS' grouped with the preference of young consumers on PC 2. The older (26+) consumers liked the appearance of all the apple cultivars more than the younger (18-25) consumers, except for GS which was liked significantly more by the younger consumers (Fig. 10). Older consumers liked the appearance of 'FU' more than they liked 'BB' and 'GS' while younger consumers preferred the appearance of 'GS' to both that of 'FU' and 'BB'

Fig. 11 illustrates the interaction between *region ethnic group, gender* and *cultivar preference* for apple appearance. PC 1 and PC 2 accounted for 65.9% and 27.1%, respectively, of the variability in the appearance preference responses of consumers from the different region, ethnic groups and gender. The appearance preference of all the consumers was explained on PC 2. With the exception of Gauteng black female consumers whose appearance preference associated more with 'PL', 'HC' and 'RG', the other black consumers from both Gauteng and Kwa-Zulu Natal associated with the appearance of 'GD'. The Gauteng white male associated more with the appearance of 'GS'. Most consumers liked the appearance of 'BB' and 'FU' to a lesser extent.

The mean appearance preference scores for the nine apple cultivars by consumers of the different regions, ethnic groups and genders showed significant differences for cultivar appearance preferences (Figs. 12a & b). Gauteng black male consumers preferred the appearance of 'FU', 'BB' and 'GS', significantly less than the other cultivars but their preference for the appearance of 'FU' was significantly higher than that of 'GS' (Fig. 12a). Gauteng black female consumers' preference for the appearance of 'BB' and 'FU' was significantly lower than all the other cultivars. Except for 'RG', Gauteng white male

consumers' preferred the appearance of 'GS' significantly more than the appearance of the other cultivars. Gauteng white female consumers preferred the appearance of 'PL' significantly more than the appearance of 'JY', 'GD', 'BB' and 'FU', but not significantly more than their preference for the appearance of 'HC', 'TR', 'RG' and 'GS'. They preferred the appearance of 'GD', 'BB' and 'FU' significantly less than the other cultivars.

The Kwa-Zulu Natal black male consumers' preference for the appearance of 'GD' is significantly higher than their preference for the appearance of 'TR', 'JY', 'GS', 'BB' and 'FU' but not significantly higher than their preference for the appearance of 'RG', 'HC' and 'PL' (Fig. 12b). Kwa-Zulu Natal black female consumers preferred the appearance of 'GD' significantly more than the appearance of the other cultivars, except for 'HC' and 'RG'. They preferred the appearance of 'BB' and 'GS' significantly less than the other cultivars but their preference for the appearance of 'BB' was not significantly lower than their preference for the appearance of 'FU'. Kwa-Zulu Natal Indian male consumers preferred the appearance of 'BB' and 'FU' significantly less than the appearance of the other cultivars, but their preference for the appearance of 'BB' was not significantly less than their preference for the appearance of 'GD'. 'FU' and 'BB' were preferred significantly less than all the other cultivars by the Indian female consumers.

Discussion

Correlation of descriptive and instrumental analyses

Significant correlation was observed between instrumental firmness and sour taste, crispness, crunchiness, hardness and instrumental acidity (TA). A negative correlation existed between instrumental firmness and mealiness, as well as sponginess. Cultivars such as 'JY', 'PL', 'BB', 'HC' and 'GS' were associated with instrumental firmness and TA. 'GS' was perceived as the most sour cultivar, with 'HC' as the crunchiest, hardest and crispiest but not crispier than 'GS'. In accordance with Harker *et al.* (2002a), we found that instrumental firmness measurement using the puncture tests was effective for predicting sensory texture attributes such as crispness, crunchiness, hardness and mealiness. Mealiness which is usually perceived by consumers as a negative attribute (Daillant *et al.*, 1996; Jaeger *et al.*, 1998), correlated negatively with instrumental firmness using puncture tests. In addition, Liu and King (1978), Abbott *et al.* (1984), Paoletti *et al.* (1993) and Karlsen *et al.* (1999) found a

significant correlation between sensory scores as rated by a trained panel and instrumental measurements of apple texture.

Instrumental measurement of total soluble solids (TSS) as expressed in °Brix correlated positively with sweet taste and negatively with sour taste. TA correlated significantly with sour taste and hardness, and negatively with sweet taste, sponginess and the calculated TSS/TA ratio. TSS/TA ratio correlated positively with sweet taste and sponginess and negatively with sour taste. Thiault (1970) found that TA correlated positively with sour taste in apples and Harker *et al*. (2002b) in their study involving the relationship between objective and sensory measurements of apple taste and flavour also found TA as the best predictor of sour taste. Although the current study showed a positive correlation between TSS and calculated TSS/TA ratio with sweet taste, Harker *et al*. (2002b) reported that sweet taste was difficult to predict using any of the objective methods and recommended the use of trained sensory panels for the analysis of sweet taste and flavour attributes. Contrary to weak correlations recorded for descriptive and instrumental analyses associations in the study by Van der Merwe (2013) that evaluated the predictors of fruit quality for four different apple families with probably high fruit variability, the strong correlations observed for the descriptive and instrumental analyses in this study, could be an indication that instrumental parameters can be used as primary indicators of quality.

Actual preference for eating quality

Preference differences for eating quality was found for black consumers in both age groups [(young (18-25) & older (26+)] for Gauteng and Kwa-Zulu Natal, as well as older white and older Indian consumers in Gauteng and Kwa-Zulu Natal, respectively, as against young white Gauteng (Gauteng white young) and young Indian Kwa-Zulu Natal (Kwa-Zulu Natal Indian young) consumers, respectively. Multivariate analyses revealed that the preference for eating quality of young white Gauteng and young Indian Kwa-Zulu Natal consumers was closely associated with textural attributes such as crispness, hardness, crunchiness and juiciness. The preference of the young white Gauteng and young Indian Kwa-Zulu Natal consumers for these textural attributes manifested in their high liking scores for crisp and firm cultivars such as ‘HC’, ‘PL’ and ‘JY’. They tolerated sour taste, thus illustrated a liking for ‘GS’. They disliked mealiness, which is considered a negative texture attribute (Daillant *et al*., 1996;

Jaeger *et al*., 1998) and this manifested in their low liking scores for 'GD' and 'RG'. This preference for sour and firm cultivars is in agreement with the findings of Van der Merwe (2013) for young (18-25) consumers in the Stellenbosch area of Western Cape Province and suggests that young white consumers throughout South Africa might display the same preferences. The close association of the preference patterns of the young white Gauteng and young Indian Kwa-Zulu Natal consumers tend to suggest that the preference for eating quality of Indian consumers are closely related to that of the white consumers. The young white Gauteng and young Indian Kwa-Zulu Natal consumers' preference for attributes such as crispness, crunchiness, hardness and juiciness and tolerance for sour taste and dislike for mealiness suggest they could be quite European-like in their eating quality preference pattern. The eating patterns of white South African consumers have been reported as being European (Viljoen and Gericke, 2001a; Manning, 2009), i.e., a preference for crispness, firmness, juiciness and tolerance for sour taste but a dislike for mealiness (Daillant *et al*., 1996; Jaeger *et al*., 1998). However, the apple eating quality preferences of Danish children aged 9-13 years associated with apple flavour, perfumed flavour and sweetness but not sour taste, juiciness and mealiness (Kühn and Thybo, 2001).

Flavour attributes, particularly sweet taste, were important drivers of liking for all black consumers irrespective of region and age group, as well as Gauteng white and Kwa-Zulu Natal Indian consumers in the older age group. This was evident in their higher liking scores for cultivars such as 'FU' and 'TR' with the highest TSS to TA ratio. These consumers disliked sour taste but tolerated mealiness. The differences in the preference pattern of young black consumers as against young white Gauteng and young Indian Kwa-Zulu Natal consumers could be as a result of differences in culture. It is well known that food preferences can be affected by differences in cultural backgrounds (Prescott, 1998). Additionally, genetic and cultural factors, as well as age tend to play a large role in how various individuals perceive sweet taste (Stevens and Cain, 1993; Fukunaga *et al*., 2005; Bretz *et al*., 2006; Keskitalo *et al*., 2007; Mizuta *et al*., 2008). The black consumers' preference for sweet taste could be as a result of reduced taste sensitivity to sucrose among Sub-Saharan African populations (Fushan *et al*., 2009), therefore the tendency for their preference of higher levels of sweetness. Sweet taste being the attribute that drives black consumer preference for apple eating quality was also in accordance with results from the study by Van der Merwe (2013) who found that a high percentage of the black and coloured

consumers preferred sweet taste and disliked sour taste. Older white Gauteng and older Indian Kwa-Zulu Natal consumers associated with sweet taste like the black consumers did. The greater preference for sweet taste of the older age group (26+) consumers' compared to the young age group (18-25) consumers in this study is consistent with Van der Merwe's (2013) findings for consumers' in the 26-35 and 36+ age groups in the Stellenbosch area of the Western Cape (Van der Merwe, 2013). However, older black and coloured consumers in the Western Cape Province preferred sweet taste more than the older white consumers (Van der Merwe, 2013). Therefore, the preference pattern for older white consumers may not be consistent throughout SA and the lower association of older white Western Cape consumers with sweet taste could be because they reside in the area where apples are grown. Jaeger *et al.* (1998) found no cross-cultural difference between British and Danish consumers while Nova Scotia and British Columbia consumers did not differ significantly in their preference for apple flavour and texture (Cliff *et al.*, 1999).

The greater association of the eating quality preference of Gauteng white and Kwa-Zulu Natal Indian consumers' in the older age group with that of black consumers rather than with young white and Indian consumers might be explained by age group influence. In addition to cultural and genetic variations, age also plays a large role in sweet taste perception (Stevens and Cain, 1993; Fukunaga *et al.*, 2005; Bretz *et al.*, 2006; Keskitalo *et al.*, 2007; Mizuta *et al.*, 2008). Physiological changes that occur as individuals' age tend to influence their perception of food (Chauhan *et al.*, 1987; Schiffman, 1994) especially their aroma and taste perceptions (Stevens *et al.*, 1984). Older consumers have higher taste thresholds compared to young consumers (Chauhan *et al.*, 1987; Stevens *et al.*, 1995; Zandstra and de Graaf, 1998) and thus tend to have a higher preference for sweetness. Other age-related preference differences have also been found. For example, Hungarian children and young consumers had a preference for firmer cultivars (Racskó *et al.*, 2009a). However, contrary to these findings, Pèneau *et al.* (2006) found that differences in age, gender and apple consumption habits did not play a significant role in consumer preference for apple taste. It is also worthy to note that major contributors to the perception of taste (sour and bitter) are gender and age (Hyde and Feller, 1981).

Male and female consumers differed in their preferences for eating quality. Male consumers showed a significant association with sweet taste and preferred 'FU' and 'TR' significantly more than female consumers. Female consumers' preference for eating quality did not correlate positively with sweet taste. Although Wardle *et al*. (2001) observed little difference in preference with respect to gender, Baker and Wardle (2003) indicated that there are some gender preference differences. Reynolds *et al*. (1999) observed a difference with respect to gender in the consumption of fruits and vegetables in a study that sought to examine the association between gender and ethnicity. However, a number of studies attributed these differences to level of nutritional knowledge among males and females (Crawford and Baghurst, 1990; Tate and Cade, 1990; Parmenter *et al*., 2000). Also, Grogan (1997) found that men consume sweet snacks more readily than women.

Preference for appearance

Young and older consumers differed in their preference for appearance of 'GS'. Young consumers' liking of the appearance of green 'GS' reflects their eating quality liking of this firm and sour cultivar. Older consumers disliked sour taste and also disliked the appearance of green 'GS'. Except for black female consumers in the Gauteng province, black consumers generally liked the appearance of yellow-green 'GD', which depicts their liking for sweetness. According to Clydesdale (1993), there is a positive association between the colour red, and sweet taste. Steyn (2012) ascribed this taste and colour association to the fact that as fruits ripen, they generally increase in both red colouration and sweetness. Green peel colour is associated with sour taste (Clydesdale, 1993; Daillant *et al*., 1996; Shankar *et al*., 2010) and perceived to be crisp and firm, while yellow peel colour is an indication of ripeness (Lau, 1988; Kingston, 1992).

Consumers of the different regions, ethnic groups, age groups and genders were least familiar with BB which was the least preferred cultivar in terms of appearance liking. In addition to 'BB', older age group consumers were also least conversant with 'FU'. This study therefore agrees with Harker *et al*. (2003) that familiarity with a specific apple cultivar influences the preference for that cultivar. Although a higher percentage of consumers in all regions and ethnic groups (Gauteng black, Gauteng white, Kwa-Zulu Natal black and Kwa-Zulu Natal Indian), as well as age groups (18-25 and 26+) were less familiar with 'BB', the cultivar

which is most likely the least known, purchased and consumed is 'HC'. This is because there is only one orchard of the cultivar HC in SA and fruit can only be purchased at Woolworths, one of the upmarket food stores. This erroneous indication could be as a result of the cultivar name. The name reflects a sweet, crisp apple, which is likely to be the preference of most of the consumers (Daillant *et al*., 1996; Jaeger *et al*., 1998; Van der Merwe, 2013; Bonany *et al*., 2014). It seems that when consumers are sure that they either know or do not know a particular cultivar, they indicate their preferences accordingly. However, when consumers believe that they should know a cultivar or are uncertain whether they know it or not, they give it an intermediate score. Consumer scientists should obviously interpret such data with caution and with the necessary insight in the subject matter.

Conclusions

In the evaluation of the attributes that drive the preference for apple eating quality and appearance of black, white and Indian consumers in Gauteng and Kwa-Zulu Natal, this study revealed that black consumers, as well as older (+26) white and older (+26) Indian consumers' preference for eating quality associates with sweet taste. The eating quality preferences of young white consumers in Gauteng, as well as young Indian consumers in Kwa-Zulu Natal are closely associated with attributes such as crispness, crunchiness, hardness and juiciness. Thus local marketers and distributors could target black, older white and older Indian consumers and supply the geographical location where these consumers are concentrated with sweet tasting cultivars. Young white and young Indian consumers collectively are a target group for crisp, firm and moderately sour cultivars. In large areas of South Africa, it is still possible to target specific ethnic groups. Ethnic groups in South African cities, towns and rural areas still live in generally homogenous neighbourhoods served predominantly by certain distinct supermarket chains. For example, within the Shoprite/Checkers group, U-Save generally services lower income neighbourhoods, Shoprite serves middle income groups whereas Checkers serves higher income groups (Shoprite Holdings Limited, 2014).

The similarity in trends of this study with a previous study carried out with black, coloured and white consumers in the Western Cape confirms that black and older South African consumers could be a target group for sweet tasting cultivars, while young South African

consumers could be targeted with firm and moderately sour cultivars. However, the preference of white consumers in the Western Cape for crisp and firm cultivars compared to older white consumers in Gauteng who prefer sweet tasting cultivars may be an indication that the taste preferences of older white consumers are not consistent throughout South Africa. Therefore, marketers and distributors could target the older white consumers in the Western Cape region where apples are grown with crisp, firm and moderately sour cultivars. Targeting consumers with their desired apple types will ensure consumer satisfaction and could thereby increase apple sales considerably. Local breeders and cultivar developers could make use of information generated from this study for breeding and evaluating potential new cultivars with desired attributes for specific groups of consumers.

Even though 'FU' was preferred in terms of eating quality assessment, its appearance as well as the appearance of 'BB' was the least preferred as a result of their dull and mottled appearances, as well as the low familiarity with 'BB' and 'FU'. In addition to embarking on educational programmes and awareness creation with regard to cultivar familiarity, local breeders and cultivar developers could focus on breeding and developing cultivars with bright, shiny and attractive colours or appearances to help boost consumer demand for apples.

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Table 1 Descriptors of sensory attributes used for the sensory analysis of apple fruit (adapted from Daillant-Spinnler *et al*., 1996).

Attributes	Description	Scale
Sweet taste	One of basic tastes, e.g. sucrose	0 = None 100 = Prominent sweet taste
Sour taste	One of basic tastes, e.g. citric acid	0 = None 100 = Prominent sour taste
Apple flavour	Associated with typical apple flavour	0 = None 100 = Prominent apple flavour
Astringency	Dries the surface of the mouth, i.e. tannic acid	0 = None 100 = Prominent astringency
Bitterness	One of basic tastes e.g. quinine, caffeine	0 = None 100 = Prominent bitterness
Crispness	Sound generated when biting into apple with front teeth	0 = None 100 = Prominent crispness
Hardness	Force to bite into apple with molar teeth	0 = None 100 = Very hard
Crunchiness	Ease of disintegration when chewing with molar teeth	0 = None 100 = Prominent crunchiness
Juiciness	Amount of juice released by sample during chewing	0 = None 100 = Extremely juicy
Mealiness	Over-ripe soft, dry and floury texture	0 = None 100 = Prominent mealiness
Sponginess	Spongy or springy texture	0 = None 100 = Prominent sponginess
Peel toughness	Measure of how tough the peel is	0 = None 100 = Prominent toughness

Table 2 Means of measured total soluble solids (TSS), titratable acidity (TA), calculated ratio of total TSS and TA (TSS/TA) and maturity indexes - firmness and dry matter content (DMC) for the nine apple cultivars. Means ± standard deviation (SD) with different alphabetical letters differ significantly. Means were separated by least significant difference (LSD) (5%).

Cultivar	**TSS (°Brix)**	**TA (Malic acid %)**	**TSS/TA**	**Firmness (N)**	**DMC (%)**
Braeburn	12.2 ± 0.12^{cd}	0.63 ± 0.02^{ab}	19.2 ± 0.61^{cd}	72.3 ± 1.05^{a}	24.0 ± 0.00^{bcd}
Pink Lady®	14.1 ± 0.29^{ab}	0.60 ± 0.03^{ab}	23.6 ± 1.42^{cd}	73.5 ± 0.85^{a}	26.7 ± 2.08^{ab}
Fuji	13.6 ± 0.64^{ab}	0.25 ± 0.04^{d}	55.5 ± 8.89^{a}	64.8 ± 0.25^{abc}	24.7 ± 1.53^{bcd}
Golden Delicious	13.2 ± 0.25^{abc}	0.37 ± 0.05^{c}	36.3 ± 5.46^{b}	47.8 ± 0.29^{d}	23.0 ± 1.00^{d}
Granny Smith	11.2 ± 0.51^{d}	0.67 ± 0.04^{a}	16.8 ± 1.67^{d}	69.1 ± 0.30^{ab}	23.3 ± 0.58^{cd}
Honeycrisp	13.4 ± 1.42^{ab}	0.53 ± 0.16^{b}	26.8 ± 6.89^{c}	70.3 ± 1.37^{a}	26.0 ± 1.00b^{c}
Royal Gala	13.1 ± 0.42^{bc}	0.35 ± 0.04^{cd}	38.0 ± 4.02^{b}	56.6 ± 0.48^{cd}	23.3 ± 1.15^{cd}
Joya™	13.3 ± 0.36^{abc}	0.56 ± 0.05^{ab}	23.9 ± 2.78^{cd}	74.6 ± 0.70^{a}	29.0 ± 2.65^{a}
Topred	14.3 ± 1.15^{a}	0.28 ± 0.01^{cd}	51.3 ± 5.71^{a}	57.4 ± 0.45^{bcd}	26.3±2.52^{ab}
P-value	***0.0014***	***<0.0001***	***<0.0001***	***0.0023***	***0.0036***

Table 3 Correlation matrix variables (sensory and instrumental quality variables) included in principal component analysis.

Variables	Flavour	Sweet	Sour	Astringent	Bitterness	Peel toughness	Crispness	Crunchiness	Hardness	Juiciness	Mealiness	Sponginess	Firmness	TSS	TA	TSS/TA	DMC
Flavour	**1**	0.541	-0.012	-0.014	0.263	0.008	-0.084	-0.063	-0.068	0.151	-0.191	0.257	0.035	0.439	0.118	-0.079	0.472
Sweetness	0.541	**1**	**-0.792**	-0.179	0.420	-0.314	-0.446	-0.405	-0.480	-0.031	0.146	**0.790**	-0.406	**0.863**	**-0.703**	**0.729**	0.283
Sourness	-0.012	**-0.792**	**1**	0.115	-0.432	0.455	**0.711**	**0.685**	**0.734**	0.428	-0.587	**-0.855**	**0.704**	**-0.709**	**0.971**	**-0.930**	0.084
Astringency	-0.014	-0.179	0.115	**1**	**0.767**	**0.783**	0.308	0.259	0.369	-0.019	-0.100	-0.300	0.038	-0.030	0.011	0.092	0.035
Bitterness	0.263	0.420	-0.432	**0.767**	**1**	0.454	-0.146	-0.162	-0.070	-0.289	0.171	0.231	-0.301	0.462	-0.478	0.547	0.214
Peel toughness	0.008	-0.314	0.455	**0.783**	0.454	**1**	**0.725**	**0.677**	**0.757**	0.373	-0.612	-0.579	0.519	-0.160	0.320	-0.158	0.385
Crispness	-0.084	-0.446	**0.711**	0.308	-0.146	**0.725**	**1**	**0.993**	**0.980**	**0.766**	**-0.886**	**-0.796**	**0.869**	-0.257	0.656	-0.500	0.368
Crunchiness	-0.063	-0.405	**0.685**	0.259	-0.162	**0.677**	**0.993**	**1**	**0.981**	**0.754**	**-0.874**	**-0.783**	**0.887**	-0.186	0.651	-0.503	0.426
Hardness	-0.068	-0.480	**0.734**	0.369	-0.070	**0.757**	**0.980**	**0.981**	**1**	0.651	**-0.831**	**-0.833**	**0.859**	-0.249	**0.683**	-0.547	0.431
Juiciness	0.151	-0.031	0.428	-0.019	-0.289	0.373	**0.766**	**0.754**	0.651	**1**	**-0.902**	-0.321	0.585	-0.069	0.410	-0.248	0.168
Mealiness	-0.191	0.146	-0.587	-0.100	0.171	-0.612	**-0.886**	**-0.874**	**-0.831**	**-0.902**	**1**	0.522	**-0.763**	0.137	-0.541	0.370	-0.432
Sponginess	0.257	**0.790**	**-0.855**	-0.300	0.231	-0.579	**-0.796**	**-0.783**	**-0.833**	-0.321	0.522	**1**	**-0.824**	0.586	**-0.816**	**0.739**	-0.168
Firmness	0.035	-0.406	**0.704**	0.038	-0.301	0.519	**0.869**	**0.887**	**0.859**	0.585	**-0.763**	**-0.824**	**1**	-0.201	**0.720**	-0.593	0.554
TSS	0.439	**0.863**	**-0.709**	-0.030	0.462	-0.160	-0.257	-0.186	-0.249	-0.069	0.137	0.586	-0.201	**1**	-0.598	0.620	0.523
TA	0.118	**-0.703**	**0.971**	0.011	-0.478	0.320	0.656	0.651	**0.683**	0.410	-0.541	**-0.816**	**0.720**	-0.598	**1**	**-0.974**	0.140
TSS/TA	-0.079	**0.729**	**-0.930**	0.092	0.547	-0.158	-0.500	-0.503	-0.547	-0.248	0.370	**0.739**	-0.593	0.620	**-0.974**	**1**	-0.066
DMC	0.472	0.283	0.084	0.035	0.214	0.385	0.368	0.426	0.431	0.168	-0.432	-0.168	0.554	0.523	0.140	-0.066	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 4 Attributes of the consumers expressed as percentage of the total consumer group (n=579) for black, white and Indian consumers.

Consumer attributes	Gauteng Black	Gauteng White	Kwa-Zulu Natal Black	Kwa-Zulu Natal Indian	Total
Age					
Young (18-25)	20	14	23	9	66
Older (26+)	9	8	11	6	34
Gender					
Male	10	6	15	8	39
Female	18	16	20	7	61
Education					
Tertiary	18	11	22	12	64
Grade 12 or Matric	9	11	8	3	31
Grade 11 or below	1	0	4	0	5
Employment status					
Student	21	14	24	9	68
Assistant	2	1	1	1	5
Administrative	2	3	1	2	8
Professional	2	4	1	3	10
Other	1	0	8	0	9
Fruit buy					
Frequent (≤ 2-3x week)	7	7	18	5	37
Less frequent (≤ 1x month)	22	14	17	10	63
Apple buy					
Frequent (≤ 2-3x week)	7	2	17	2	28
Less frequent (≤ 1x month)	22	20	17	13	72
Consumption of apples					
Frequent (≤ 3-5x week)	16	11	24	6	57
Less frequent (≤ 1x month)	13	11	10	9	43
Total consumer group (%)	29	22	34	15	100

Table 5 Familiarity with the nine apple cultivars by consumers from the different ethnic groups, age groups and gender from the Gauteng Province and Kwa-Zulu Natal Province expressed as percentage of total consumers of each respective group.

Cultivar	Gauteng Black (n=164)	Gauteng White (n=126)	Kwa-Zulu Natal Black (n=199)	Kwa-Zulu Natal Indian (n=90)	Young (18 -25) (n=382)	Older (26+) (n=197)	Male (n=226)	Female (n=353)	Total consumer (%)
Braeburn	27	19	30	21	24	29	28	24	26
Pink Lady®	45	58	48	40	47	50	38	54	48
Fuji	41	40	36	32	36	41	38	37	38
Golden Delicious	81	86	88	79	82	88	77	89	84
Granny Smith	68	92	72	83	76	79	67	83	77
Honeycrisp	46	33	50	39	46	39	46	42	44
Royal Gala	48	49	46	46	42	57	44	49	47
Joya™	34	31	33	27	33	29	33	31	32
Topred	57	51	47	38	46	55	44	53	49

Table 6 Familiarity with the nine apple cultivars by consumers with different educational background and employment status expressed as percentage of total consumers of each respective group.

Cultivar	Tertiary (n=368)	Grade 12 or Matric (n=180)	Grade 11 or below (n=31)	Student (n=394)	Assistant (n=26)	Administrative (n=47)	Professional (n=59)	Other (n=53)	Total consumer (%)
Braeburn	27	22	23	24	38	34	24	26	26
Pink Lady®	50	45	42	46	73	51	56	36	48
Fuji	39	34	39	36	35	47	47	30	38
Golden Delicious	84	85	81	81	100	91	95	83	84
Granny Smith	76	83	48	74	85	96	92	62	77
Honeycrisp	44	42	42	45	65	36	27	43	43
Royal Gala	49	46	39	42	73	57	63	45	47
Joya™	32	32	29	32	42	40	20	28	32
Topred	51	47	39	46	73	64	53	45	49

Table 7 Apple purchase and consumption of the nine apple cultivars expressed as percentage of the total consumers of each respective group.

Cultivar	Frequent apple purchase (≤ 3-5x week) (n=163)	Less frequent apple purchase (≤ 1x month) (n=416)	Frequent apple consumption (≤ 3-5x week) (n=331)	Less frequent apple consumption (≤ 1month) (n=248)	Total consumer (%)
Braeburn	30	24	27	24	26
Pink Lady®	56	44	54	39	48
Fuji	43	36	40	34	38
Golden Delicious	87	83	87	81	84
Granny Smith	75	77	78	76	77
Honeycrisp	52	40	47	39	43
Royal Gala	50	46	50	44	47
Joya™	35	30	32	31	32
Topred	52	48	54	43	49

Table 8 ANOVA table with main and interaction effects for region ethnic group, gender and age with actual preference of apple eating quality.

Factor	DF	Pr > F
Region ethnic group	3	**<0.0001**
Gender	1	0.0783
Region ethnic group*Gender	3	**0.0041**
Age	1	**<0.0001**
Region ethnic group*Age	3	**0.0113**
Gender*Age	1	**0.0495**
Region ethnic group*Gender*Age	3	0.1925
Region ethnic group*Gender(Consumer)	563	**<0.0001**
Cultivar	8	**<0.0001**
Region ethnic group*Cultivar preference	24	**<0.0001**
Gender*Cultivar preference	8	**0.0049**
Region ethnic group*Gender*Cultivar preference	24	0.3004
Age*Cultivar preference	8	**<0.0001**
Region ethnic group*Age*Cultivar preference	24	**0.0385**
Gender*Age*Cultivar preference	8	0.1931
Region ethnic group*Gender*Age*Cultivar preference	24	0.5498

Table 9 ANOVA table with main and interaction effects for region ethnic group, gender and age with actual preference of apple appearance.

Factor	DF	Pr > F
Region ethnic group	3	**<0.0001**
Gender	1	0.084
Region ethnic group*Gender	3	**0.0015**
Age	1	**<0.0001**
Region ethnic group*Age	3	0.0815
Gender*Age	1	0.9322
Region ethnic group*Gender*Age	3	**0.007**
Region ethnic group*Gender(Consumer)	563	**<0.0001**
Cultivar	8	**<0.0001**
Region ethnic group*Cultivar preference	24	**<0.0001**
Gender*Cultivar preference	8	0.168
Region ethnic group*Gender*Cultivar preference	24	**0.0016**
Age*Cultivar preference	8	**<0.0001**
Region ethnic group*Age*Cultivar preference	24	0.0728
Gender*Age*Cultivar preference	8	0.3307
Region ethnic group*Gender*Age*Cultivar preference	24	0.3813

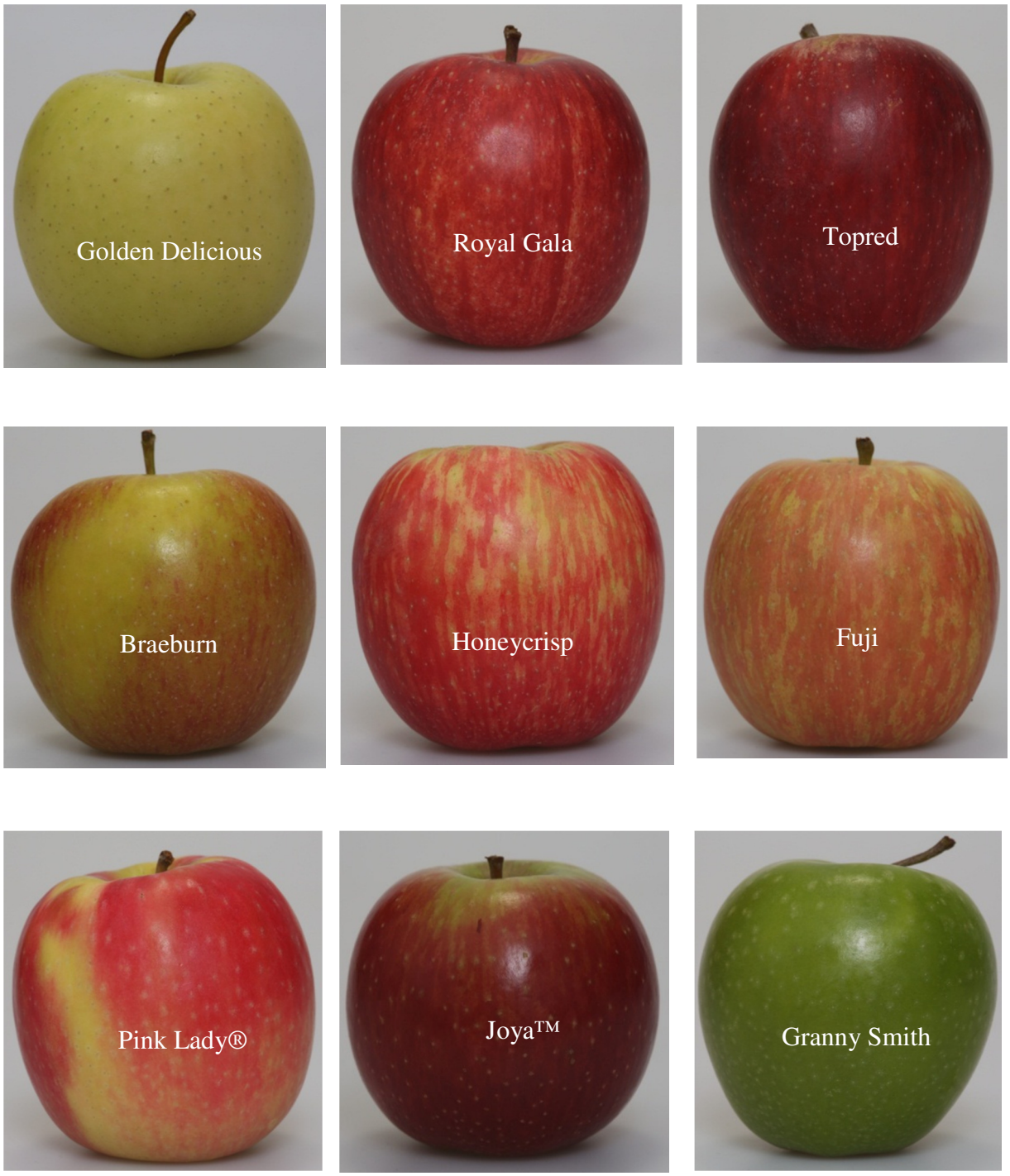
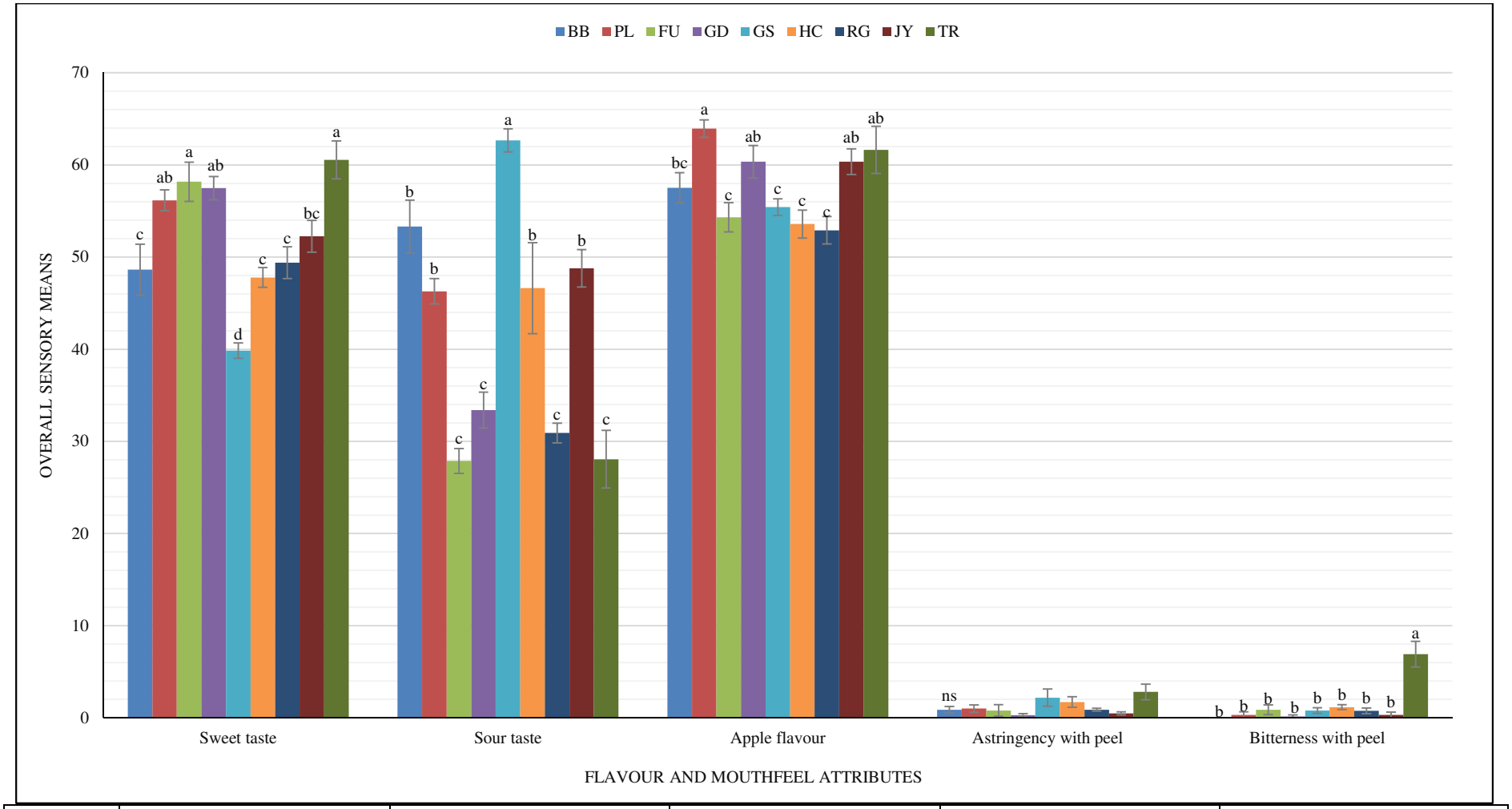
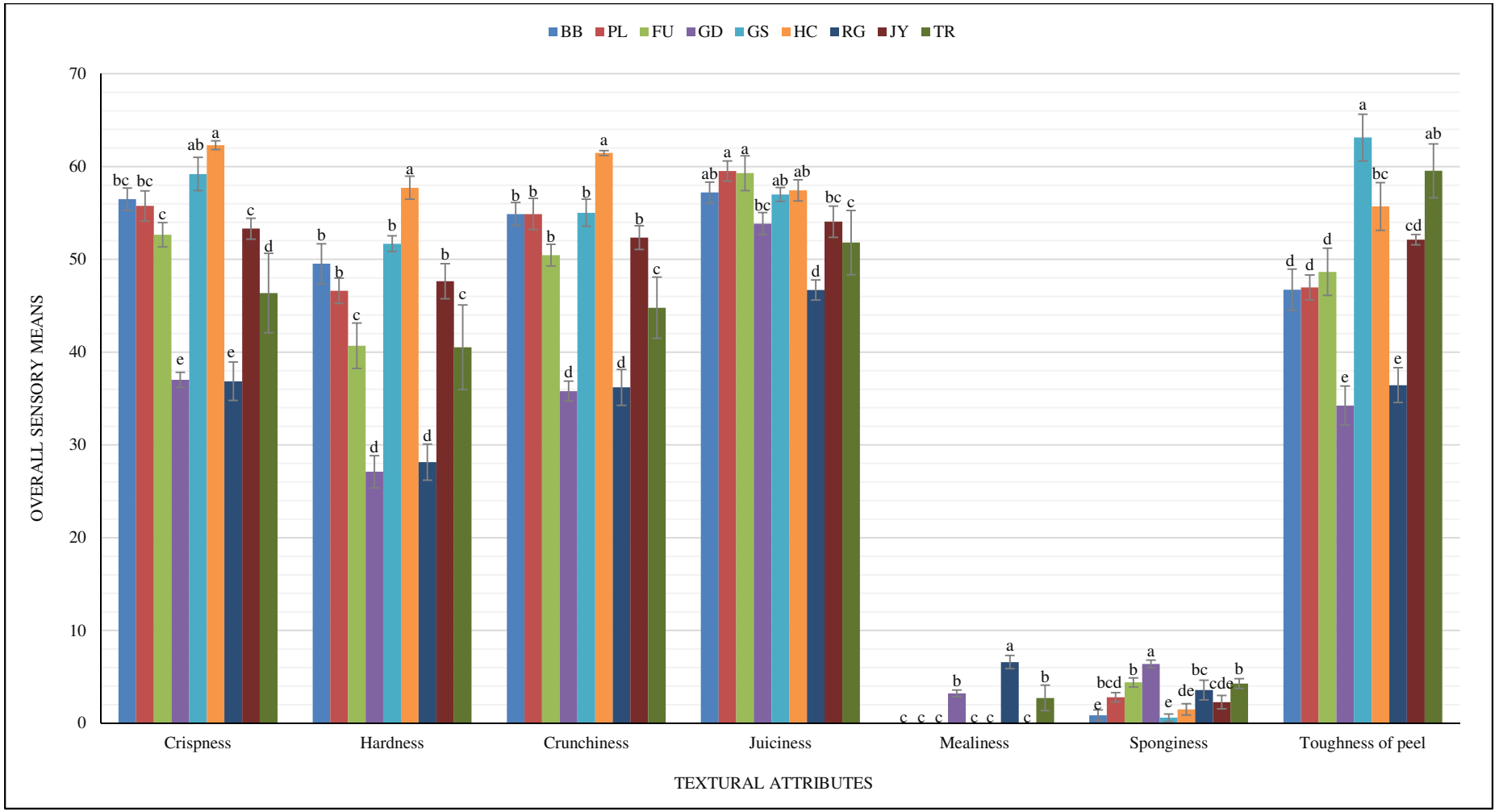


Figure 1 Photographs of all nine apple cultivars analysed in the eating quality test.



P-value	***<0.0001***	***<0.0001***	***0.0004***	***0.0737***	***<0.0001***

Figure 2 Overall means of apple flavour and mouth feel measured on a 100 mm line scale during descriptive sensory analysis of nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5%level of significance.



P-value	***<0.0001***	***<0.0001***	***<0.0001***	***0.0004***	***<0.0001***	***<0.0001***	***<0.0001***

Figure 3 Overall means of sensory textural attributes measured on a 100 mm line scale during descriptive sensory analysis of nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

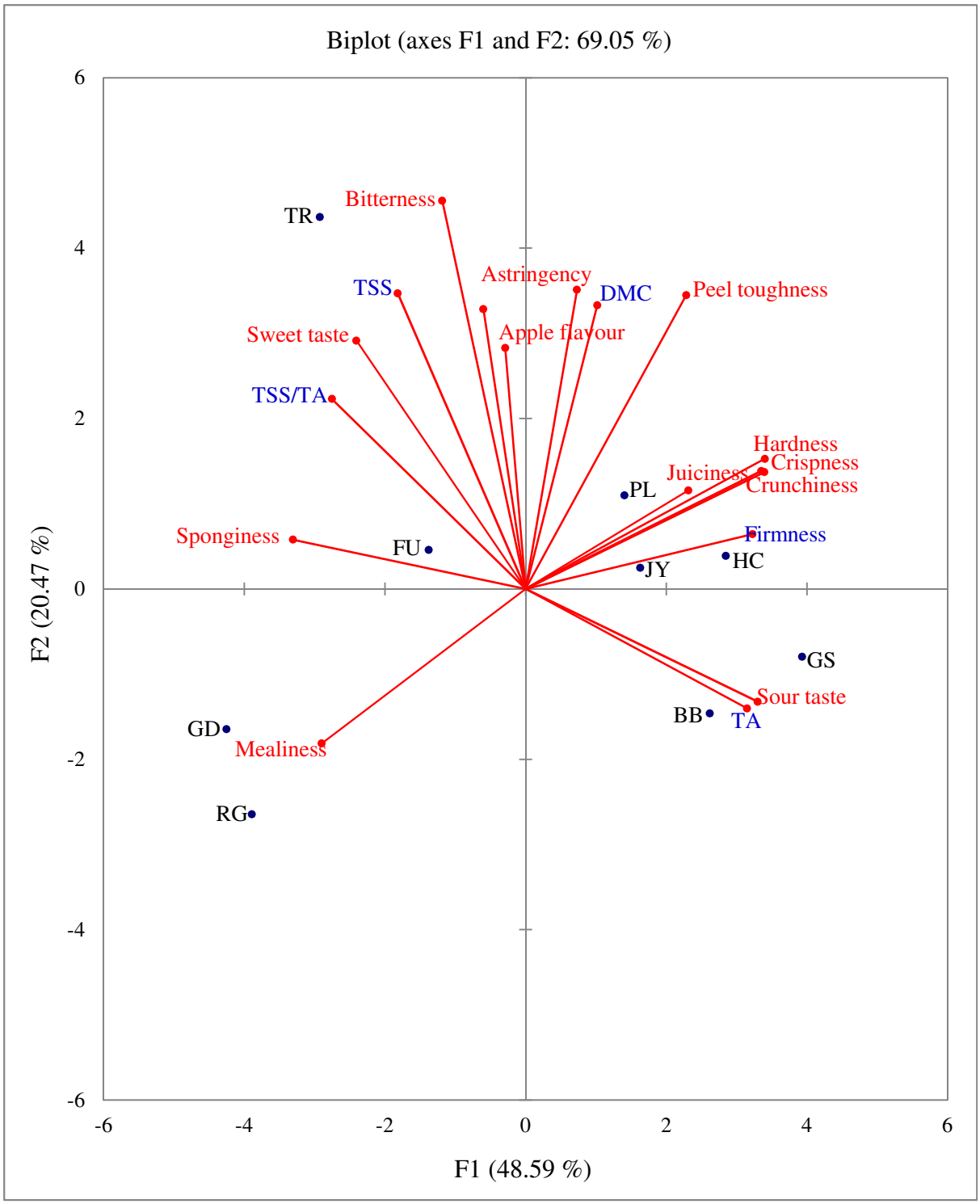


Figure 4 Principal component analysis bi-plot indicating the correlation between overall sensory attributes and instrumental measurements of apple fruit from nine cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR).

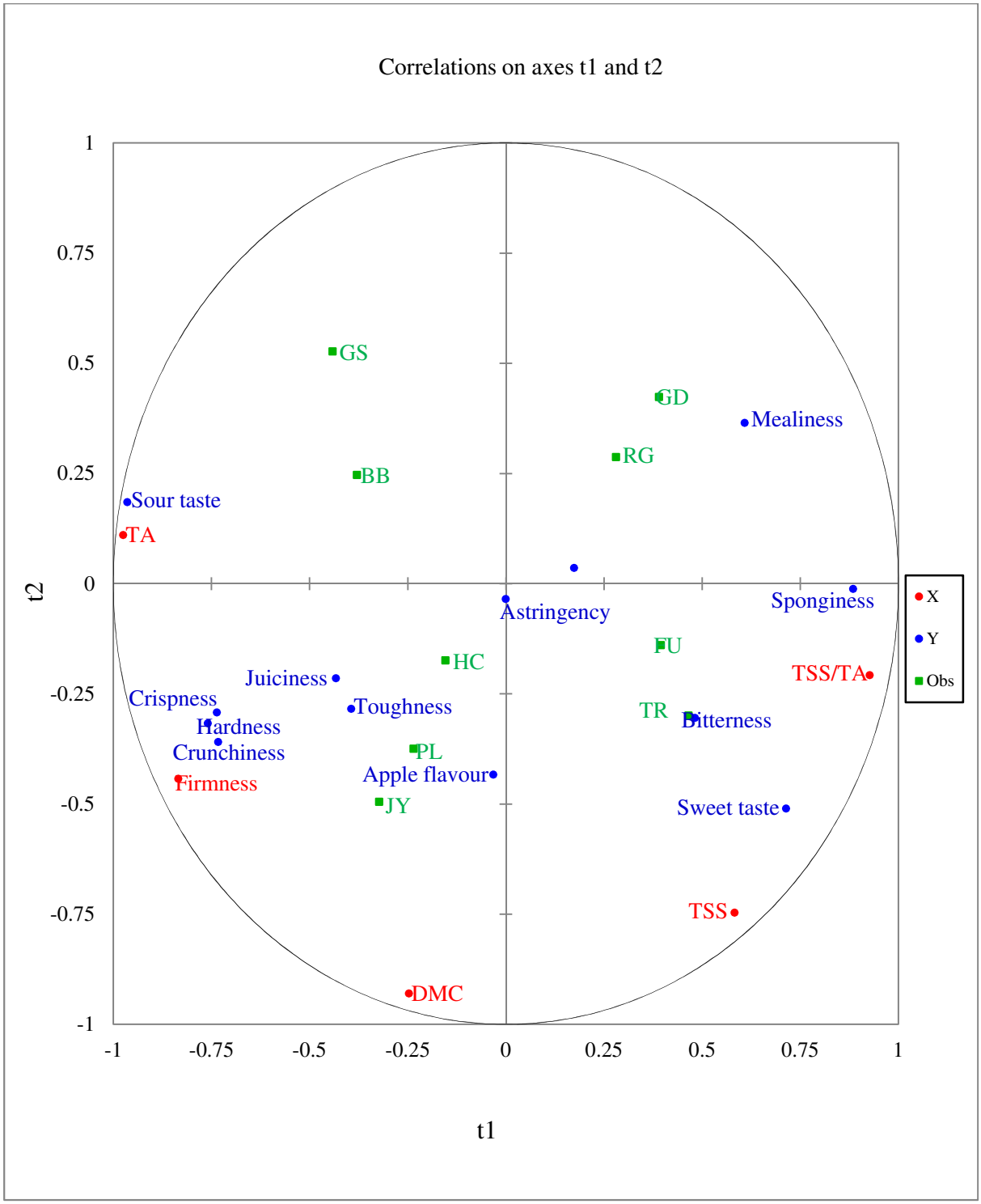


Figure 5 Partial least squares regression plot indicating the correlation between overall sensory attributes and instrumental measurements of apple fruit from nine cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR).

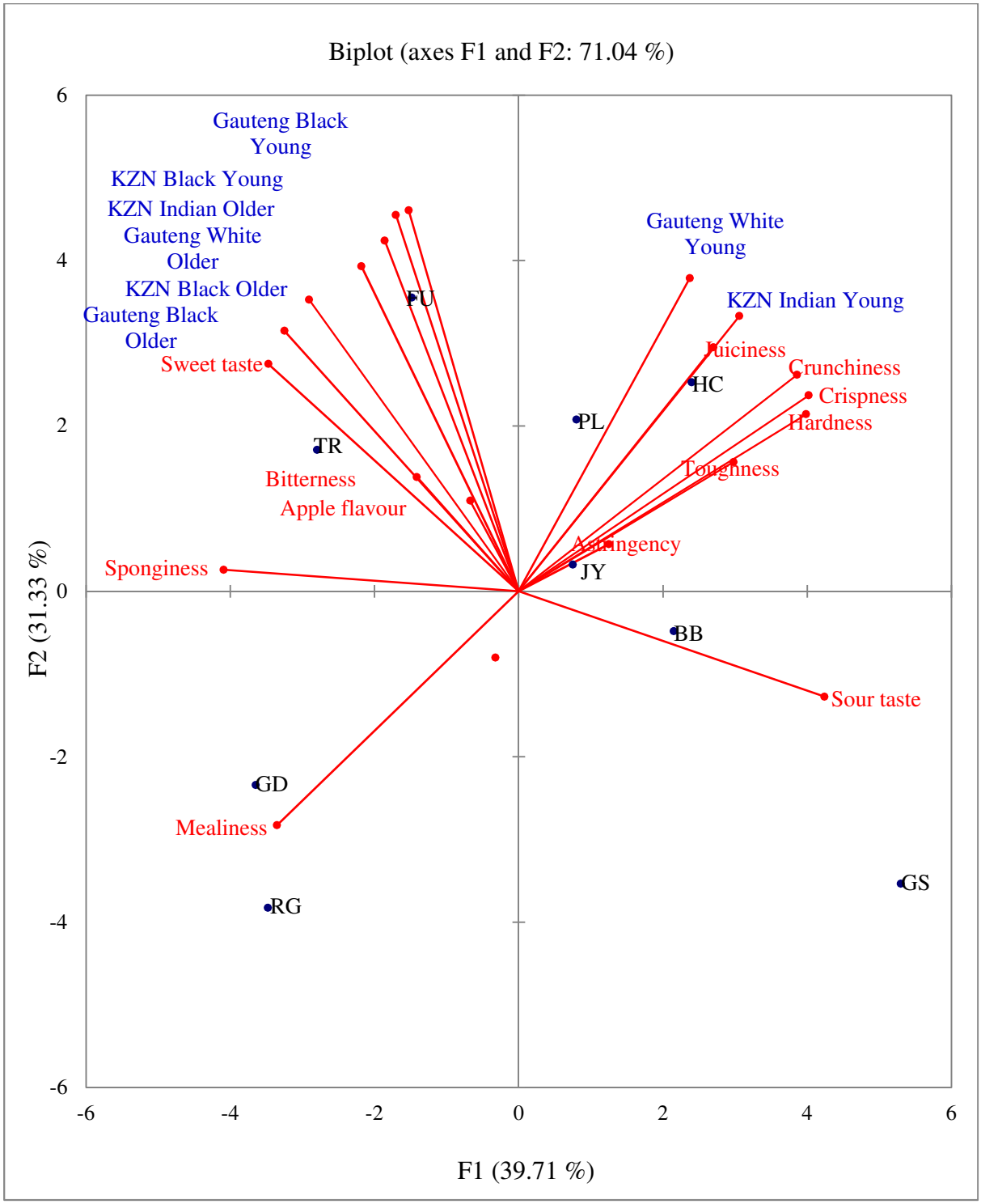


Figure 6 Principal component analysis bi-plot indicating the position of the consumer preference for overall eating quality for different ethnic (black, white and Indian) and age (young and older) groups for Gauteng and Kwa-Zulu Natal Provinces in relation to sensory attributes of apple fruit from nine cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR).

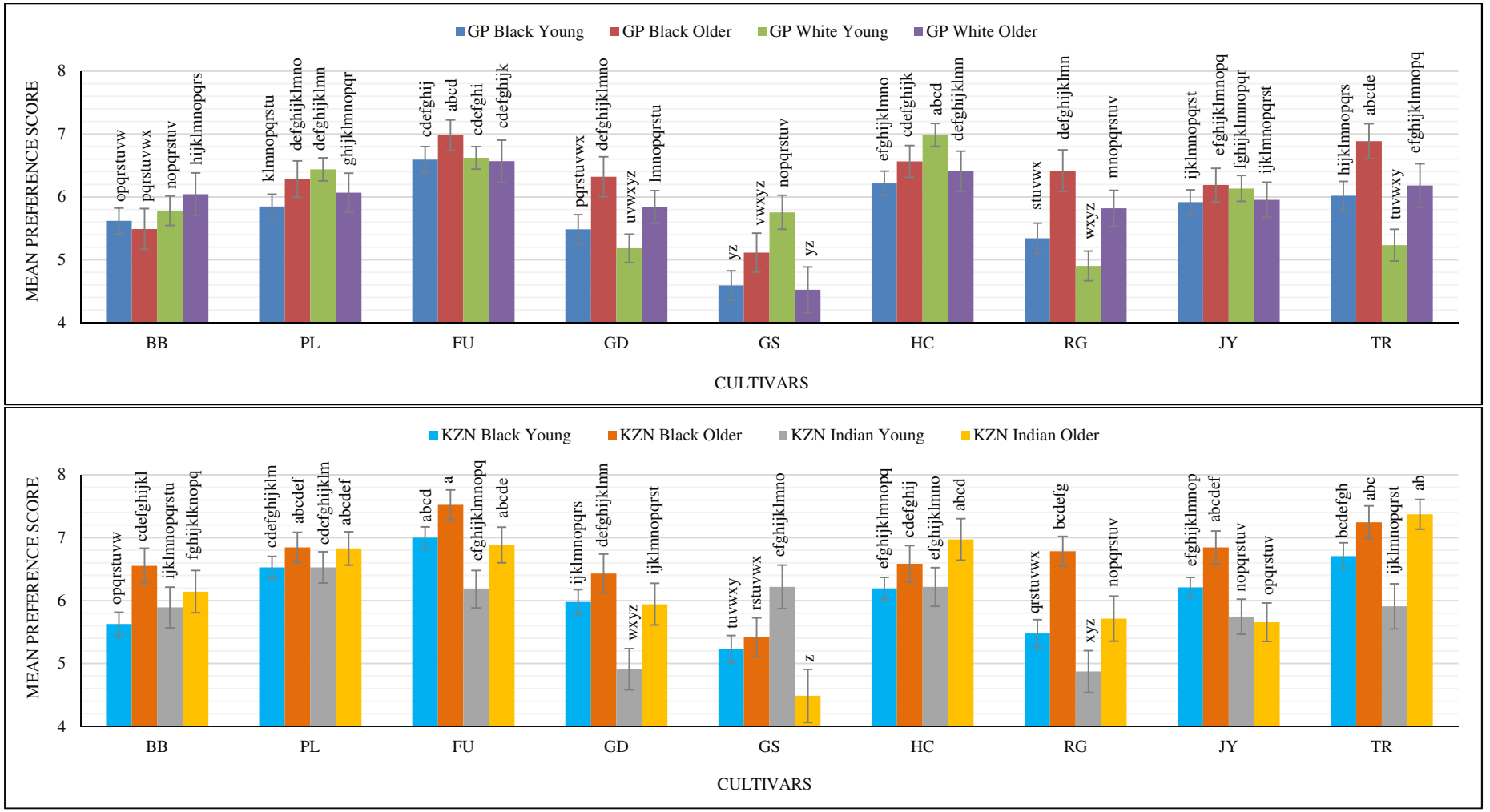


Figure 7a & b Mean preference scores for the nine apple cultivars in the actual eating quality analysis, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by consumers of different ethnic and age groups from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means +standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

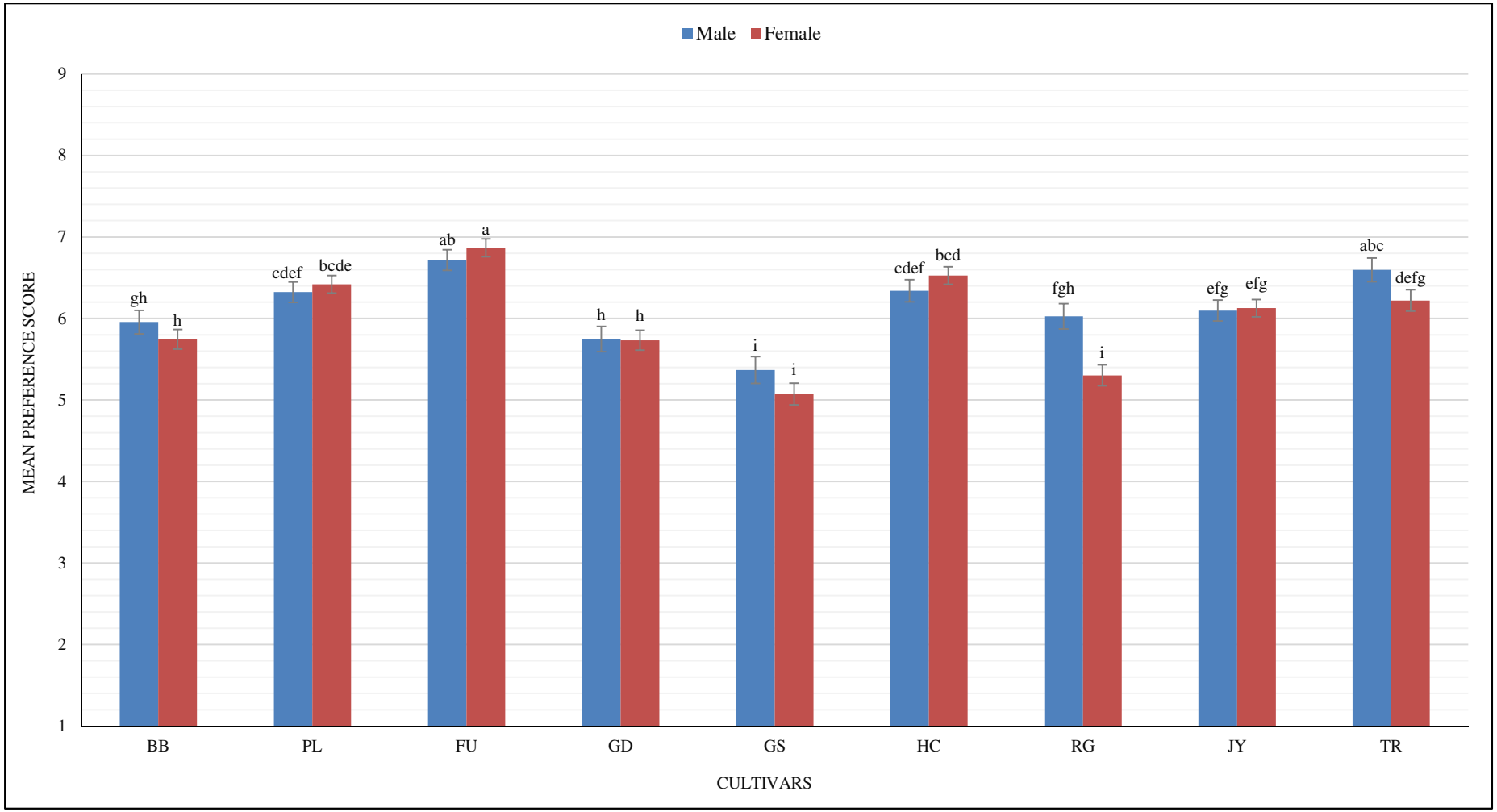


Figure 8 Mean preference scores for the nine apple cultivars in the actual eating quality analysis, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by male and female consumers. Means +standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

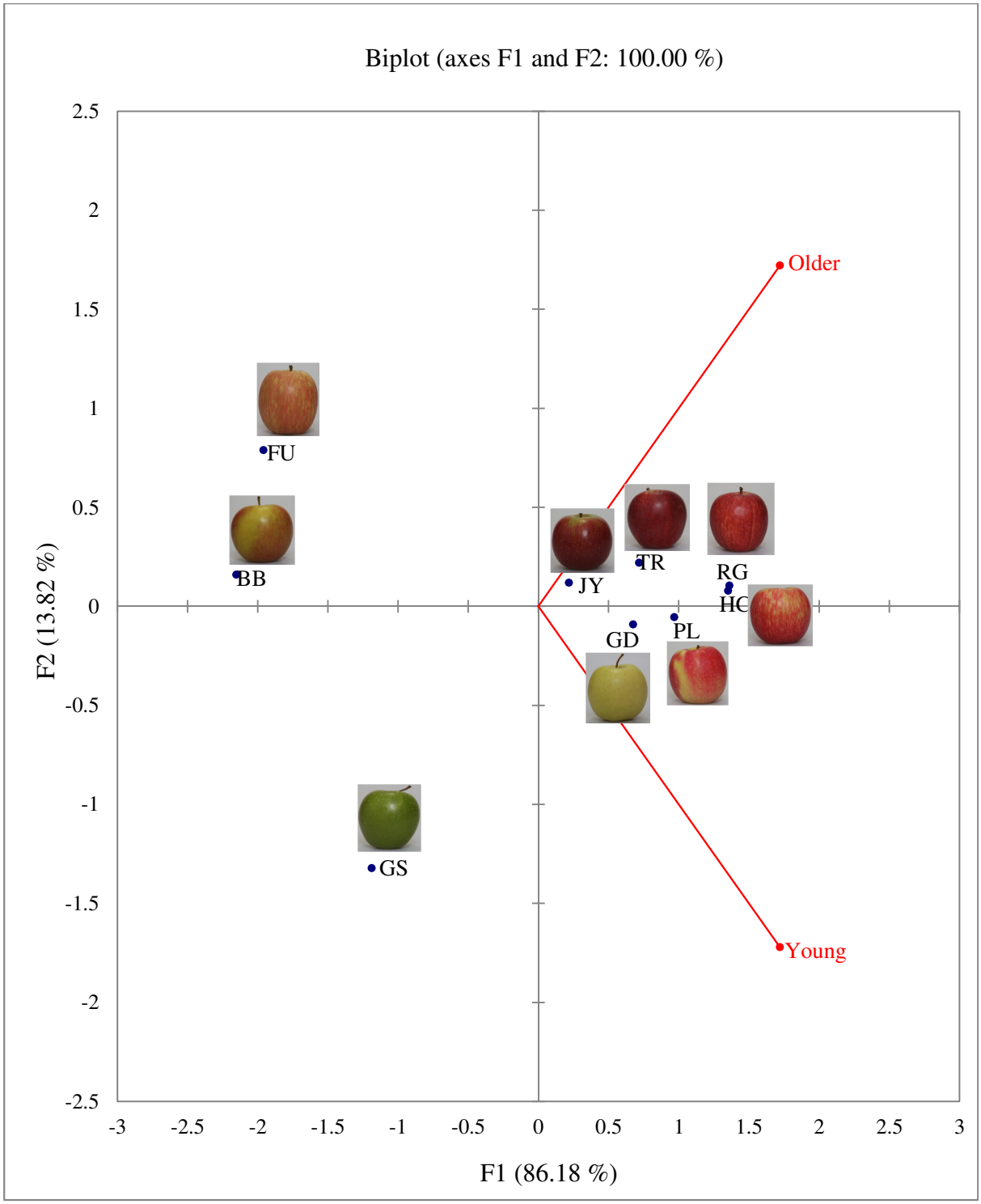


Figure 9 Principal component analysis bi-plot indicating the preference for appearance of the young (18-25) and older (26+) age groups for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR). The photographs used for the study are displayed in the plot.

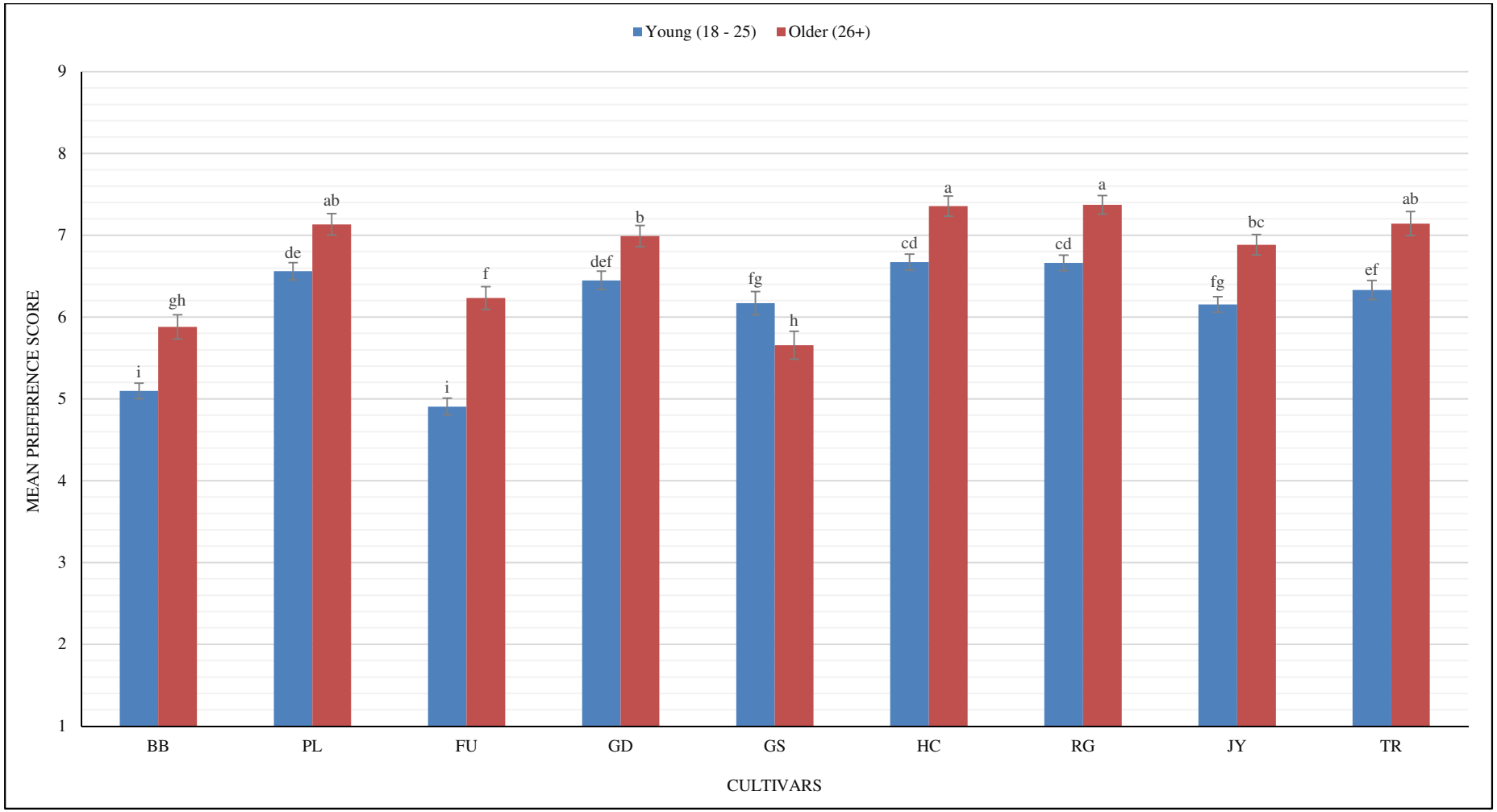


Figure 10 Mean appearance preference scores for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by the young (18-25) and older (26+) age group consumers. Means +standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

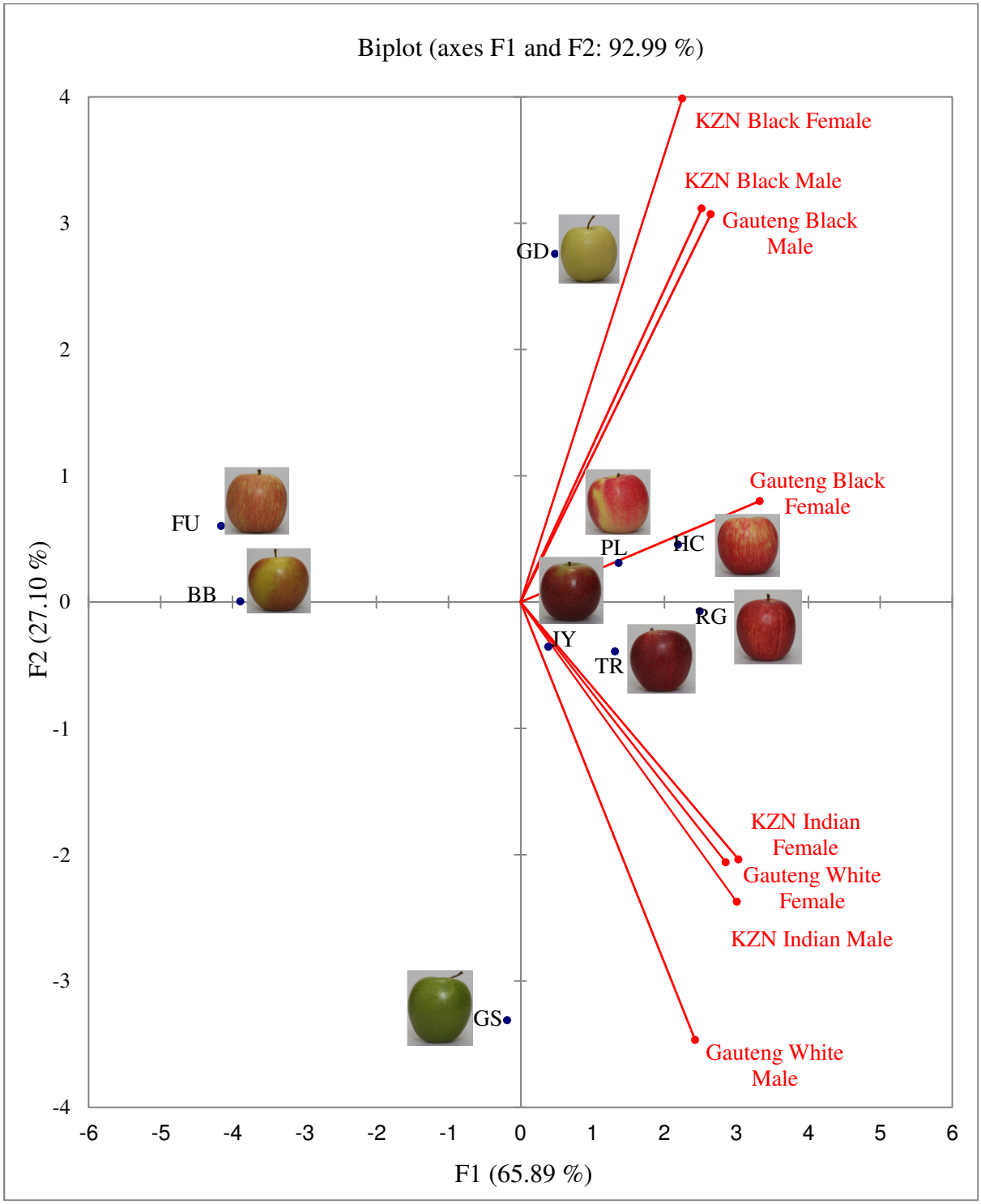


Figure 11 Principal component analysis bi-plot indicating the preference for appearance of the different ethnic groups (black, white and Indian) and gender (male and female) for Gauteng and Kwa-Zulu Natal Provinces for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR). The photographs used for the study are displayed in the plot.

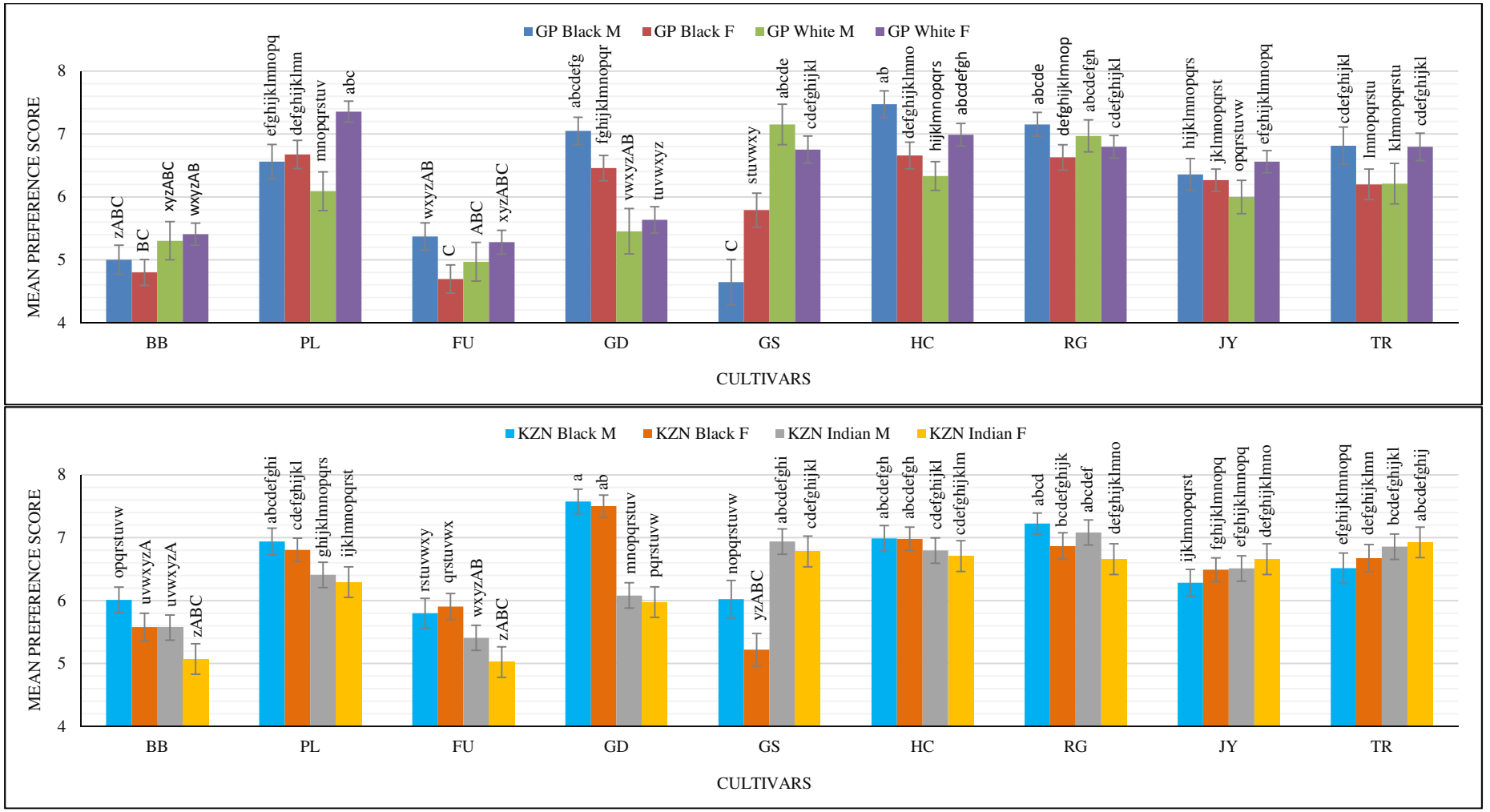


Figure 12a & b Mean appearance preference scores for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by consumers of different ethnic groups and gender from the Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

PAPER 2: CONCEPTUAL APPLE QUALITY PREFERENCES AMONG SOUTH AFRICAN CONSUMERS OF DIFFERENT ETHNIC AND AGE GROUPS AND POSSIBLE IMPLICATIONS FOR RETAILERS

Abstract

Consumers of different ethnic and age groups may differ in what they perceive as acceptable apple quality and may also respond differently to varying purchase factors. Consumers' perception of apple quality and purchase factors largely influence their decision to buy one apple type or the other. Hence, in this study we assessed apple quality, purchase and consumption factors that influence consumer preference. Black, white and Indian consumers of two age groups, young (18-25) or older (26-61) participated in consumer studies conducted in Pretoria, Gauteng Province and Durban, Kwa-Zulu Natal Province. Consumers' conceptual preferences for a variety of taste and appearance aspects, purchase and consumption factors, person responsible for buying fresh fruit and preferred shop of apple purchase were analysed on a 9-point hedonic scale. Region, ethnic and age groups, as well as gender interacted significantly for consumers' conceptual preference for the parameters tested. Black and older white and Indian consumers indicated preference for sweet taste, a dislike of sour taste and greater tolerance for softness and mealiness, as was apparent in their liking of 'Golden Delicious', red and striped red colour, but dislike for 'Granny Smith' and full green colour. On the contrary, young Indian and white consumers indicated a general preference for crisp texture, a tolerance of sour taste and a dislike for softness and mealiness, which was evident in their liking of 'Granny Smith' and for full green colour, but dislike of yellow peel colour. Female consumers generally indicated a greater preference for 'Pink Lady®' compared to male consumers. This could be indicative of positive branding of 'Pink Lady®' amongst female consumers and illustrative of how successful branding could potentially influence sales of other cultivars, particularly considering that females are predominantly responsible for buying fresh fruits. Consistent with previous studies, apple colour was the most important purchase factor with size also important for younger consumers and size and price also important for older consumers. Amongst consumer groups, black Kwa-Zulu Natal consumers rated price significantly higher. All consumers groups buy apples from Pick 'n Pay, while older white Gauteng consumers also buy from Woolworths, Fruit & Veg and Spar. Older Indian Kwa-Zulu Natal consumers buy from Fruit & Veg and buy equally from Checkers and Woolworths. Since consumers' conceptual preferences generally corresponded with their

actual preferences, except in the case of unfamiliar cultivars, wholesalers and retailers can substantially increase sales if the various consumer groups are targeted with their preferred apple cultivar or type. This is possible in South Africa where many retailers predominantly target or are favoured by a distinct clientele. Considering our data, PicknPay should be stocked with a wide range of apple cultivars, Shoprite with more sweet tasting cultivars while Woolworths, Fruit & Veg, Checkers and Spar should be preferentially stocked with firm, moderately sour to sweet tasting cultivars to maximise sales. Informative marketing aiming to acquaint most South Africa consumers with non-familiar cultivars could boost sales even further.

Keywords *Malus x domestica* (Borkh.), consumer groupings, consumer conceptual preference, purchase factors, principal component analysis.

Introduction

While apple exports to the United Kingdom, which is the traditional market for apple exports from South Africa, has rapidly declined from 37% to 21% from 2009 to 2014 (HORTGRO, 2014), apple sales on the South African fresh fruit domestic market is currently 27% (HORTGRO, 2015). The increase in domestic sales corresponds with an increase in the number of middle and high income consumers since 1994 (SAARF, 2012) and preference for fresh over canned fruit in the middle to upper income brackets (GAIN Report, 2012). Considering the fickleness of sales on exports markets and the increasing importance of the local market, it is becoming imperative to understand the intrinsic and extrinsic factors that drive the local consumers' preference for apple eating quality and appearance. Knowledge of the apple eating quality and appearance preferences of local consumers could help marketers target consumers according to their preferences and could assist local apple breeders to develop potential new cultivars with desired attributes that match the preferences of local consumers.

Van der Merwe (2013) investigated the attributes that drive the preference for apple quality of black, coloured and white consumers of varying age groups in the Stellenbosch area of the Western Cape Province of South Africa. Both ethnic and age differences in general apple eating quality and appearance preferences were found. The study furthermore revealed differences in conceptual preferences for eating quality attributes, cultivars and factors

relating to apple purchase decisions between the different ethnic and age groups studied. Sweetness and juiciness were key attributes for all ethnic and age groups, although white consumers also liked apple flavour. White consumers, as well as 18-25 age group consumers disliked mealiness. In addition to apple peel colour being the most important purchase factor for all ethnic and age groups, black and coloured consumers also indicated that fruit size and price influence their purchase decisions, while white consumers associated with cultivar loyalty and cultivar name indication on the packaging. The youngest (18-25) consumers associated with colour and size, while older (26-35, 36+) consumers associated with price and cultivar loyalty. However, the conceptual preference patterns of consumers in the Western Cape region may not necessarily apply to the rest of the country. Hence, Van der Merwe (2013) cautioned that further research was needed to determine whether her findings also extended to other regions and ethnic groups in South Africa.

Consumer preferences for eating quality attributes tend to differ between cultures (Prescott and Bell, 1995). Druz and Baldwin (1982) reported that Korean and Nigerians compared to North American Caucasians differed in their preference for sweetness. In terms of factors that affect purchase decisions, international studies on conceptual preferences showed that German consumers stated freshness of a fruit or vegetable as the most important purchase factor (AgV, 1981) and Swiss consumers' choice of apple is influenced by factors such as taste, aroma and freshness (Péneau *et al*., 2006). Péneau *et al*. (2006) indicated that freshness was an important factor in apple choice irrespective of consumers' age and gender. Age group played a significant role in Hungarian consumers' conceptual preference for apple quality and purchase factors (Racskó *et al*., 2009). Consumers in the <25 years age group indicated that taste was the most important attribute that influenced their choice of apple followed by fruit size and colour (Racskó *et al*., 2009). Cultivar and origin were not important factors in their apple choice decision. Australian consumers' decision to purchase a specific apple was influenced by apple quality attributes (Kirchhoff *et al*., 2008). Assessing French consumers' likes and dislikes of apple quality using comment analysis, crunchiness, sweetness and juiciness were found to be the most liked sensory factors, while mealiness was disliked (Symoneaux *et al*., 2012). Peel colour is one of the most important factors that influence consumer preference for apple quality and fruit sale (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002). Consumers' perception of fruit quality, especially in relation to fruit taste as well as their decision to buy apples, is largely influenced by fruit peel

colour (Jaeger and MacFie, 2001; Shankar *et al.*, 2010; Steyn, 2012). Although consumers in the United Kingdom considered quality more important than price (Market Review, 1996), Hungarian consumers between the ages of 25 and 50 considered price as an important factor influencing their purchase decision (Racskó *et al*., 2009).

Consumer preferences vary from country to country and region to region (Cliff *et al*., 2002; Bonany *et al*., 2013) and cultivar preference played a large role when Jaeger *et al*. (1998) studied British and Danish consumers' liking for fresh and aged apples. Australian and Japanese consumers differed in their perception of fruitiness of orange and grapefruit juices (Prescott *et al*., 1997; Prescott, 1998). Samoan consumers resident in New Zealand perceived an apple product tagged for home consumption as ideal while on the contrary, New Zealand consumers viewed product tagged for consumption while out of home as ideal (Jaeger, 2000).

Attributes driving the preference of consumers of different ethnic and age groups in the Gauteng and Kwa-Zulu Natal Provinces of South Africa for actual eating quality and appearance of apples were reported in Paper 1. This paper will focus on the parameters driving the conceptual preferences of consumers of different ethnic and age groups in Gauteng and Kwa-Zulu Natal for apple quality, purchase and consumption factors. The aims of this research were to: 1) Determine if different consumer groups (black Gauteng, white Gauteng, black Kwa-Zulu Natal and Indian Kwa-Zulu Natal) and age groups significantly affect consumers' conceptual preferences for apple quality, purchase and consumption factors, and 2) establish the main factors driving the conceptual preference for black, white and Indian consumers and for consumers from two different age groups.

Materials and methods

Consumer recruitment and analysis

The nine different apple cultivars used in the study, consumer recruitment and consumer conceptual preference analysis that were conducted are reported in Paper 1 and will not be repeated here. Consumers' conceptual preferences were analysed for different aspects including thirteen eating quality attributes (astringent, bitter taste, crisp texture, juiciness, mealiness, prominent apple aroma, prominent apple flavour, slight apple flavour, slight internal browning, soft ripe texture, sour taste, spongy texture and sweet taste), eight peel colour and colouring patterns (full green, bi-colour pink, blush pink, full red, bi-colour red ,

blush red, striped red and full yellow), nine different apple cultivars that were the same as those used in the actual liking evaluation (Paper 1) (Braeburn, Pink Lady®, Fuji, Golden Delicious, Granny Smith, Honeycrisp, Royal Gala, Joya™ and Topred), and finally eight purchase and consumption factors (colour of the apple, familiarity with cultivar, loyalty to specific cultivars, cultivar name indication on the packaging, peeling an apple before eating it, price, shape and size of the apples). Consumers' indication of the person responsible for buying fresh fruit (self, spouse, parents and other), state in which the apple is consumed (fresh, baked, cooked, fresh in fruit salads or consumed in any other form) and shop of apple purchase (Checkers, Food Lovers Market, Fruit and Veg, green grocery, hawker, Pick 'n Pay, Shoprite, Spar, Woolworths or other) was also analysed. Fruit and Veg as well as Spar targets the entire LSM market (LSMs 1-10). Pick 'n Pay and Shoprite targets clientele in LSMs 4-7, Checkers targets customers in LSMs 8-10, while Woolworths shop outlet serves consumers in LSMs 9 and 10.

Statistical procedures

The purpose of the study was to analyse the interaction between consumer group and age group in their conceptual preference for various aspects relating to apple quality and other factors that influence consumers' decision to purchase and consume apples. The conceptual data for each aspect, i.e. eating quality attributes, peel colour and colouring patterns, cultivar name, and purchase and consumption factors, were subjected to analysis of variance (ANOVA).

In order to compare consumer demographic characteristics that contributed to conceptual preference for the different aspects, these characteristics were subjected to a n x 4 x 2 x 2 factorial ANOVA with the following factors: Aspect (where n is the number of levels within an aspect), consumer group (black Gauteng, white Gauteng, black Kwa-Zulu Natal and Indian Kwa-Zulu Natal), age group [(young (18-25), older (26+)] and gender (male and female). The older age group (26+) ranged from 26 to 61, with the age distribution being 26-30, 31-40, 41-50, 51-60 and 61+. However, the majority of the older age group consumers were found in ages 26 to 41. SAS statistical software (SAS, version 9, 1999, Cary, North Carolina, USA) was used for the analyses. Statistical significance was defined at $P \leq 0.05$. Student's t-LSD's (Least Significant Difference) were calculated at a 5% significance level

and used to determine whether conceptual preference for the different aspects differed significantly between different gender, age and consumer groups.

Principal component analysis (PCA) was performed in order to study the effect of different demographic groups (consumer group, age group and gender) on consumers' conceptual preferences. In order to reduce variation and the number of points on the corresponding figures, mean values of the conceptual preference scores were calculated for significant combinations of consumer_group, age_group and gender with the different parameters tested. These means were taken as input to a weighed PCA of the correlation matrix. Means for the different significant combinations were projected onto separate PCA spaces. To clarify the linear relationship between conceptual preference for the different demographic groups, Pearson's correlation coefficients were calculated with XLSTAT software (Addinsoft, Version 2013.5.07, New York, USA) (Pèneau *et al.*, 2006).

Results

Reporting in this paper will focus on consumers' conceptual preference for specific aspects of eating quality (e.g. sweet taste, sour taste, crispness, juiciness etc.), peel colour and colouring patterns (e.g. full green, blush pink, bi-colour red etc.), cultivar preference (same cultivars used in the actual liking evaluation) (Paper 1), as well as factors that may influence consumers' purchase decisions. Reporting will also be done on consumers' indication of who in the household buys fresh fruit (fresh fruit buyer), shop of apple purchase and state of apple consumption (e.g. fresh, cooked, etc.).

Conceptual preference for eating quality attributes

There were significant three and four way interactions for consumers' conceptual preference for eating quality attributes (Table 1). The four way interactions will not be reported. Consumer group and age group, as well as consumer group and gender interacted significantly with consumers' conceptual preference for eating quality attributes (Table 1). The consumer group and age group interaction with consumers' conceptual preference for eating quality attributes showed that consumers generally gave high preference scores for juiciness (scores ranged from 7.4 to 8.1), crisp texture (6.3 to 8.1), sweet taste (7.2 to 8.1), prominent apple flavour (6.0 to 7.6) and prominent apple aroma (6.3 to 7.0) (Figs. 1a & b).

Young black Gauteng consumers indicated that they liked juiciness and crisp texture comparably and also more than other attributes but their preference for crisp texture did not differ significantly from their preference for sweet taste (Fig. 1a). Older black Gauteng consumers liked sweet taste, juiciness and crisp texture comparably and also more than other attributes. Young white Gauteng consumers indicated a comparable likeness for crisp texture and juiciness and also more than other attributes. Older white Gauteng consumers indicated that they liked crisp texture, juiciness, prominent apple flavour, sweet taste and prominent apple aroma comparably but their preference for crisp texture was significantly higher than their preference for sweet taste and prominent apple aroma. Their preference for prominent apple flavour was considerably higher than the preference of black and young Indian consumers for this attribute. Similarly, their dislike for slight apple flavour was also greater than that of black and older Indian consumers. Young black Kwa-Zulu Natal consumers indicated that they liked juiciness and sweet taste comparably but their preference for sweet taste did not differ significantly from their preference for crisp texture (Fig. 1b). Older black Kwa-Zulu Natal consumers indicated that they liked juiciness and sweet taste comparably and also more than other attributes. Crisp texture was scored slightly lower than juiciness and sweet taste. In terms of the highest preferences, black Gauteng and black Kwa-Zulu Natal consumers differ in the slightly lower preference of the latter group for crisp texture. Young Indian Kwa-Zulu Natal consumers indicated that they liked juiciness, crisp texture and sweet taste comparably and also more than other attributes. Older Indian Kwa-Zulu Natal consumers indicated that they liked juiciness, sweet taste and crisp texture comparably and also more than other attributes but their preference for crisp texture did not differ significantly from their preference for prominent apple flavour and prominent apple aroma.

Consumers' generally gave low preference scores for soft ripe texture (scores ranged from 3.8 to 5.5), slight apple flavour (2.7 to 4.8), sour taste (3.4 to 5.4), mealiness (2.1 to 4.0), spongy texture (2.6 to 3.6), astringency (1.8 to 3.5), bitter taste (1.5 to 3.8) and slight internal browning (1.5 to 3.8) (Figs. 1a & b). Older black Kwa-Zulu Natal consumers gave a significantly higher score for soft ripe apple texture, compared to the other consumer groups except for older black Gauteng consumers. Young white Gauteng and young Indian Kwa-Zulu Natal consumers gave considerably higher scores for sour taste (young white Gauteng consumers scored 4.9 and young Indian Kwa-Zulu Natal consumers scored 5.4). White and older Indian consumers had a greater dislike than black consumers for mealiness while young

Indian consumers also disliked mealiness more than Kwa-Zulu Natal black and older Gauteng black consumers. Indian, white and young black Gauteng consumers were less tolerant of slight internal browning (P=0.0003). Older black Kwa-Zulu Natal consumers were more tolerant of bitter taste compared to other groups and also of a soft ripe texture except for older black Gauteng consumers. Older Indian consumers were least tolerant of bitter taste but did not differ from older white consumers. Indian and white older consumers were least tolerant of astringency.

The consumer group and gender interaction with consumers' conceptual preference for eating quality attributes showed that all consumers showed a comparable high preference for juiciness and sweet taste (Figs. 2a & b). In the case of black males, these attributes were liked more than any other attribute. Black female consumers indicated that they liked juiciness, crisp texture, sweet taste, prominent apple flavour and prominent apple aroma comparably and also more than other attributes but black female Gauteng consumers liked juiciness significantly more than sweet taste, prominent apple flavour and prominent apple aroma and also liked sweet taste significantly more than prominent apple aroma (Figs. 2a & b). However, black female Kwa-Zulu Natal consumers liked juiciness and sweet taste more than prominent apple aroma and prominent apple flavour and also liked juiciness significantly more than crisp texture. White Gauteng consumers indicted that they liked crisp texture and juiciness comparably and also more than other attributes but their preference for juiciness was not significantly more than their preference for prominent apple flavour and sweet taste. Indian Kwa-Zulu Natal consumers indicated that they liked juiciness, sweet taste and crisp texture comparably and also more than other attributes (Figs. 2a & b). White Gauteng and Indian Kwa-Zulu Natal consumers indicated higher aversion for mealiness (2.0 to 2.8). Except for black female Gauteng consumers who gave a mealiness score of 2.8, the mealiness score given by black consumers ranged from 3.7 to 4.3.

Conceptual preference for peel colour and colouring patterns

Consumer group and age group as well as consumer group and gender interacted significantly with consumers' conceptual preference for peel colour and colouring patterns (Table 2).

Grouping based on consumer and age groups

The young white Gauteng consumers gave a score of 6.9 for both full green and full red peel colours, which was not significantly higher than their liking score of 6.5 for the bi-colour pink peel colour pattern (Fig. 3a). The young Indian Kwa-Zulu Natal consumers also indicated that they liked full green and full red peel colours comparably and significantly more than other peel colours and colouring patterns (Fig. 3b). Both consumer groups (young white Gauteng and young Indian Kwa-Zulu Natal) scored full yellow peel colour significantly lower than all other peel colours and colouring patterns (Figs. 3a & b). All the black consumer groups as well as older white Gauteng and older Indian Kwa-Zulu Natal consumers gave higher scores for full red apple peel colour (6.3-7.9), striped red apple peel colouring pattern (5.9-6.8) and bi-colour pink (5.8-6.8) (Figs. 3a & b). Except for older black Gauteng consumers who scored full green apple peel colour the lowest, all the other black consumer groups as well as older white Gauteng and older Indian Kwa-Zulu Natal consumers gave their lowest scores for the full yellow apple peel colour. However, their preference for full yellow peel colour was not significantly lower than their preference for full green peel colour.

The PCA bi-plot indicates the position of consumer conceptual preferences for peel colour and colouring patterns obtained for the different consumer and age groups (young black Gauteng, older black Gauteng, young white Gauteng, older white Gauteng, young black Kwa-Zulu Natal, older black Kwa-Zulu Natal, young Indian Kwa-Zulu Natal and older Indian Kwa-Zulu Natal) in relation to the eight different colour and colouring patterns studied, with the first (PC 1) and second principal components (PC 2) accounting for 78.0% and 14.9%, respectively of the variability in consumer response (Fig. 4). Young white Gauteng and young Indian Kwa-Zulu Natal consumers were significantly correlated ($r=0.95$; $P=0.0001$) in their conceptual preference for apple peel colour and colouring patterns. The PCA bi-plot showed that their preference was driven by full green peel colour but that they disliked full yellow peel colour (Fig. 4). The conceptual preferences of black Gauteng and Kwa-Zulu Natal, older white Gauteng and older Indian Kwa-Zulu Natal consumers for apple peel colour and colouring patterns strongly correlated (Fig. 4). They liked full red, striped red and bi-colour pink apple peel colour and colouring pattern, but dislike full green apple peel colour.

Grouping based on consumer group and gender

Generally, all the consumer groups gave their highest liking score for full red peel colour (6.4-7.6) (Figs. 5a & b). However, black male Gauteng consumers' liking score for striped red peel colour (6.8), black female Gauteng consumers' liking score for bi-colour pink (6.0), white male Gauteng consumers' liking score for full green peel colour (6.5) and striped red peel colour did not differ significantly from their preference score for full red peel colour (Fig. 5a). White female Gauteng consumers liking score for full red peel colour (7.2) did not differ significantly from their liking score for bi-colour pink (7.0) (Fig. 5a). In addition, black male and female Kwa-Zulu Natal consumers' liking scores for striped red peel colour, full red peel colour and bi-colour pink did not differ significantly (Fig. 5b). Indian male and female Kwa-Zulu Natal consumers' liking score for full red peel colour was significantly higher than all other peel colours and colour patterns (Fig 5b). All the consumer groups scored full yellow peel colour low (3.6-5.2) (Figs. 5a & b) and black male Gauteng consumers gave their lowest liking score (4.4) for full green peel colour, which was not significantly lower than their liking scores for blush red colouring pattern (4.9) and full yellow peel colour (5.2) (Fig. 5a). Black female Kwa-Zulu Natal consumers gave a score of 4.7 to full yellow, full green peel colour and bi-colour red, (Fig. 5b). In addition, black female Gauteng, white male Gauteng and black male Kwa-Zulu Natal consumers scored bi-colour red significantly lower than they scored full yellow peel colour (Figs. 5a & b).

The PCA bi-plot indicated the position of consumer conceptual preferences for peel colour and colouring patterns obtained for the different consumer groups and genders (black male Gauteng, black female Gauteng, white male Gauteng, white female Gauteng, black male Kwa-Zulu Natal, black female Kwa-Zulu Natal, Indian male Kwa-Zulu Natal and Indian female Kwa-Zulu Natal) in relation to the eight different colour and colouring patterns studied, with the first (PC 1) and second principal components (PC 2) accounting for 80.8% and 12.2% respectively, of the variability in consumer response (Fig. 6). Although, consumers of all consumer groups and both genders grouped together and generally like full red apple peel colour as well as striped red and bi-colour pink apple peel colouring patterns, the preference of the white and Indian consumers for apple peel colour and colouring patterns were also driven by full green apple peel colour.

Conceptual preference for apple cultivar

Consumer group and age group interacted significantly with consumers' conceptual preference for cultivar. Gender also interacted significantly with consumers' conceptual preference for cultivar (Table 3).

Grouping based on consumer and age groups

The PCA bi-plot indicated the position of consumer conceptual preferences for apple cultivars obtained for the different consumer and age groups (young black Gauteng, older black Gauteng, young white Gauteng, older white Gauteng, young black Kwa-Zulu Natal, older black Kwa-Zulu Natal, young Indian Kwa-Zulu Natal and older Indian Kwa-Zulu Natal) in relation to the nine different apple cultivars studied, with the first (PC 1) and second principal components (PC 2) accounting for 55.0% and 23.2% respectively, of the variability in consumer response (Fig. 7). Older white and Indian consumers separated from other consumer and age groups on PC 1 and correlated significantly (r=0.71; P=0.033). Their conceptual preference for apple type was driven by their comparatively greater liking of 'Braeburn' (Fig. 8a & b). Older white consumers also had a distinct dislike for 'Granny Smith'. Older Indian consumers also showed a dislike for 'Granny Smith', but their preference score did not differ significantly from that of the young black Kwa-Zulu Natal consumers. These older white and Indian consumers also gave comparatively high scores for 'Pink Lady®', 'Topred' and, in the case of Indian consumers, 'Royal Gala'.

Black, young white and young Indian consumers grouped together on PC 1 and separated to a lesser extent on PC 2. No correlation existed between young white Gauteng consumers and any of the other consumer groups. These consumers gave high scores to 'Pink Lady®' and 'Granny Smith' and a relatively low score to 'Braeburn'. Older black Gauteng and young Indian consumers are located at opposite ends of the PC 2. The segregation between these consumers were driven by the young Indian consumers' dislike for 'Pink Lady®' and much greater preference for 'Granny Smith'. Young Indian Kwa-Zulu Natal consumers correlated positively with young black Kwa-Zulu Natal consumers (r=0.73; P=0.027) and also with older black Kwa-Zulu Natal consumers (r=0.71; P=0.032). Older black Gauteng consumers correlated significantly with young black Gauteng consumers (r=0.81; P=0.008), young black Kwa-Zulu Natal consumers (r=0.93; P=0.000) and also with older black Kwa-Zulu Natal

consumers (r=0.68; P=0.046). The conceptual preference of black consumers seemed to associate with 'Golden Delicious'.

Grouping based on gender

Male and female consumers only differed significantly in their preference for 'Pink Lady®', with females liking it much more than male consumers (Fig. 9). Female consumers indicated that they liked 'Golden Delicious' the most, and 'Pink Lady®' comparably. Male consumers indicated they liked 'Golden Delicious' and 'Granny Smith' comparably but rated Pink Lady® among their least preferred cultivars together with Braeburn and Joya™ (Fig. 9). Female consumers also liked 'Braeburn' and 'Joya™, the least.

Conceptual rating for importance of purchase and consumption factors

There were significant two way interactions for consumers' conceptual preference for importance of purchase and consumption factors. Age group interacted significantly with consumers' conceptual preference for importance of purchase and consumption factors (Table 4). Consumer group also interacted significantly with consumers' conceptual preference for importance of purchase and consumption factors (Table 4).

Grouping based on age groups

Both younger (18-25 years) and older (26+) consumers rated colour significantly higher than all other purchase and consumption factors (Fig. 10). Older consumers rated price and size as the next most important purchase and consumption factors. While size was of second most importance for young consumers, they rated price lower together with shape and name indication. Eating without peel was not important to any age group, even though older consumers rated it somewhat higher than the young consumers.

Grouping based on consumer group

All consumers rated colour as the most important factor that influences their purchase decisions and they rated it significantly higher than all other factors (Fig. 11). Although the overall trend was the same, consumer groups differed in their scores for all the other purchase and consumption factors. Black Kwa-Zulu Natal consumers rated price, cultivar loyalty and

familiarity significantly higher than the other consumer groups. Indian Kwa-Zulu Natal consumers scored familiarity lower than other consumer groups and name indication lower than white and black Kwa-Zulu Natal consumers. Size and shape was the second most important factors for these consumers. Size was also the second most important factor for black Gauteng consumers, together with price and name indication for black Kwa-Zulu Natal consumers and together with name indication for white consumers. Black Kwa-Zulu Natal and white Gauteng consumers scored the importance of cultivar name indication on the packaging significantly higher than the other consumer groups. Peeling apples before eating was rated the least important factor by all consumer groups but black Kwa-Zulu Natal consumers rated it significantly higher than the other consumer groups and Indian Kwa-Zulu Natal consumers rated it higher than white consumers.

Conceptual rating for person responsible for buying fresh fruit

There were significant two and three way interactions for consumers' conceptual rating for fresh fruit buyer. Consumer group and age group interacted significantly with consumers' conceptual rating for fresh fruit buyer. Gender also interacted significantly with consumers' conceptual rating for fresh fruit buyer (Table 5).

Grouping based on consumer and age groups

Older consumers indicated that they generally buy fresh fruits themselves, although the mean score was significantly lower for older Indian Kwa-Zulu Natal consumers (Fig. 12). A significantly higher number of young Indian Kwa-Zulu Natal consumers indicated that their parents are responsible for buying fresh fruits and they showed a commensurate much lower score for buying fresh fruit themselves. Other young consumers indicated that they and their parents about equally share the buying of the fresh fruits that they consume. Young white Gauteng consumers and their parents buy more or less similar amounts of the fresh fruit that these young consumers eat while young black consumers buy more fruit themselves. The spouse of older Indian consumers buy a significant amount of the fruit they consume.

Grouping based on gender

Although the overall pattern did not differ, female consumers buy significantly more and their parents significantly less fresh fruits compared to male consumers (Fig. 13).

Conceptual rating for shop of apple purchase

Consumer group and age group interacted significantly with consumers' conceptual rating for shop of apple purchase (Table 6).

Black, young white and young Indian consumers indicated that they buy significantly more apples from Pick 'n Pay than from the other shops listed in the study (Fig. 14). Older black Kwa-Zulu Natal consumers also buy from Shoprite as much as they buy from Pick 'n Pay. Older white consumers indicated that they share their apple purchases between Pick 'n Pay, Woolworths, Fruit & Veg and Spar. The older Indian Kwa-Zulu Natal consumers buy apples from Pick 'n Pay, Fruit & Veg and Checkers and they buy apples from Woolworths as much as they buy from Checkers. The Food Lovers Market and Green Grocery were generally not important for apples purchases. Young black and older Indian Kwa-Zulu Natal consumers do purchase some apples from hawkers.

Conceptual rating for state of apple consumption

In terms of consumers' rating for state in which apple is consumed, 95% of consumption was fresh (data not shown).

Discussion

Quality attributes and cultivar preference patterns

Black and older white and Indian consumers generally indicated a preference for sweet taste, a dislike for sour taste and greater tolerance for softness and mealiness. These preferences were also evident in their predilection for the cultivar, Golden Delicious, as well as their liking of full red and striped red colour and a dislike of full green colour and the cultivar Granny Smith. Young Indian and white consumers, however, indicated an overall preference for crisp texture, a tolerance of sour taste and a dislike for softness and mealiness. These preferences were apparent in their liking of 'Granny Smith', as well as their preference for full green peel colour. All consumer groups indicated a preference for juiciness. These conceptual preference patterns corroborate to a large extent our findings on actual eating quality and appearance preferences in Paper 1 in that consumer ethnicity and age influenced preference for apple cultivar and quality attributes. Our data also suggest that consumers are aware of the attributes that drive their preferences for apple quality.

Our findings are in agreement with studies by Prescott and Bell (1995) and Van der Merwe (2013) who found differences in consumer preferences between cultures and with Helgesen *et al*. (1997), Zandstra and De Graaf (1998), Racskó *et al*. (2009), as well as Van der Merwe (2013) who found that consumer preferences are influenced by consumer age. Genetic and cultural factors as well as age tend to play a large role in how various individuals perceive sweet taste (Stevens and Cain, 1993; Fukunaga *et al*., 2005; Bretz *et al*., 2006; Keskitalo *et al*., 2007; Mizuta *et al*., 2008). The black consumers' preference for sweet taste could be as a result of reduced taste sensitivity to sucrose among Sub-Saharan African populations (Fushan *et al*., 2009); therefore the tendency for their preference of higher levels of sweetness. The preference of white and Indian consumers evaluated in this study tend to associate with the general preference of European apple consumers for juiciness, crispness, tolerance for sour taste and a dislike of mealiness (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998).

The preference of young Indian and young white consumers for green and dislike of full yellow peel colour is in accordance with their preference for crisp texture and juiciness, tolerance of sour taste and dislike of mealiness. Conversely, the preference of black and older consumers for full red and striped red peel and their dislike of full green peel colour, could be due to their preference for sweet taste and dislike for sour taste. Green colour is associated with sourness (Clydesdale, 1993; Daillant-Spinnler *et al*., 1996, Shankar *et al*., 2010) and with perceived crispness and firmness (Richardson-Harman *et al*., 1998). Yellow peel colour, on the other hand, indicates ripeness and a possibly softer texture in apple (Richardson-Harman *et al*., 1998). More ripe, yellow apples have a greater likelihood to be mealy (Richardson-Harman *et al*., 1998; Paper 4). According to Lau (1988), Kingston (1992) and Steyn (2012), background peel colour progresses from green through to yellow as apples ripen. Consumer judgement of apple ripeness is influenced by visual cues (Moskowitz and Kreiger, 1993) and apple background colour was found to have a greater influence on ripeness scores than level of blush coverage (Richardson-Harman *et al*., 1998). Additionally, Richardson-Harman *et al*. (1998) found that apples with a more green background colour are associated with firmness and firm-related comments, while apples with a more yellow background are associated with softness and soft-related comments. Red colour increases consumers' subjective sweetness perception (Johnson and Clydesdale, 1982). Steyn (2012) ascribed this taste and colour association to the simultaneous increase in redness and sweetness in various fruits.

As in previous studies (Cliff *et al.*, 1999; 2002, Van der Merwe, 2013, Hamadziripi *et al.*, 2014; Van der Merwe *et al.*, 2015), cultivar familiarity played a significant role in consumer preference in this study. The appearance and eating quality liking scores were less likely to correspond for cultivars that consumers were less familiar with. For example, although many consumers liked the taste of 'Fuji' (Paper 1), consumers' generally disliked its appearance (Paper 1) and also indicated a conceptual dislike for the cultivar. Because consumers are not familiar with 'Fuji' (Table 5, Paper 1) and they do not recognise its photo or its cultivar name, they have no basis for judgement on their possible preference of its taste. Strong evidence for the role of familiarity in consumer preference of apples were presented by Hamadziripi *et al*. (2014) who found that consumers preferred the appearance of green inner canopy 'Golden Delicious' and 'Granny Smith' fruit, even though they preferred the taste of the blushed outer canopy fruit. Gamble *et al.* (2006) found that Australian and New Zealand consumers preferred the appearance of familiar pear cultivars. In agreement with Van der Merwe (2013), all age groups were familiar with and showed a high liking of 'Golden Delicious', although the youngest (18-25) age group were also familiar with and showed a high preference for 'Pink Lady®', probably because they have a positive image of the cultivar and associate it with high quality (Van der Merwe *et al*., 2015). The preference of black consumers for 'Golden Delicious' is possibly due to their familiarity with this cultivar (Paper 1) and possible association of the cultivar with sweet taste. Van der Merwe (2013) also found that black consumers preferred 'Golden Delicious' to other cultivars. 'Golden Delicious' is the most widely grown cultivar in South Africa and most of it is consumed by black African consumers, since currently about 72% of the total 'Golden Delicious' exported out of South Africa is to the rest of the African continent (HORTGRO, 2015). However, 'Golden Delicious' fruit do not sell in the African market if peel colour is not green but yellow (Henk Griessel, personal communication, July 23, 2015), possibly because consumers associate yellow peel colour with over ripeness (Richardson-Harman *et al*., 1998).

In the current study, gender also played a significant role in consumer preference for cultivar and quality attributes, in accordance with Nu *et al*. (1996) and Racskó *et al*. (2009). Black female Gauteng consumers indicated a greater preference for juiciness over sweet taste while female consumers generally indicated a greater preference for 'Pink Lady®' compared to male consumers. Black female Gauteng consumers' appearance preference associated with

'Pink Lady®' (Paper 1). We are not sure why female consumers have a preference for 'Pink Lady' compared to men, but we assume that it relates to the branding of the cultivar.

Conceptual preference of purchase and consumption factors

In agreement with Van der Merwe (2013), apple peel colour was rated the most important factor that influenced consumers' purchase decisions in this study. Fruit size was also important to both younger and older consumers. Peel colour is one of the most important factors that determines consumer preference for apple quality and influences apple sales (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002). Consumers' perception of fruit quality, especially in relation to fruit taste, as well as their decision to buy apples is largely influenced by fruit colour (Jaeger and MacFie, 2001; Shankar *et al.*, 2010; Steyn, 2012). Contrary to our findings, Racskó *et al.*, (2009) found that Hungarian consumers younger than 25 years indicated that taste was the most important attribute that influenced their choice of apple, followed by fruit size and colour. The older (26+) consumers in our study indicated that in addition to colour and size, price also influence their purchase decisions. Price was of lesser importance to younger consumers. Although consumers in the United Kingdom (UK) considered quality more important than price (Market Review, 1996), Hungarian consumers between the ages of 25 and 50 also indicated price as an important factor influencing their purchase decisions, possibly due to the lower income level among the older consumers (Racskó *et al.*, 2009). We did not evaluate the effect of income level of the various consumer groups on their purchase decisions. The higher rating for price as an important purchase factor by black Kwa-Zulu Natal consumers probably relates to the generally larger proportion of black consumers in South Africa belonging to the lower Living Standard Measure (LSM)® groups having less dispensable income (Wortley and Tshwaedi, 2002; Holborn, 2012). These consumers would be more price sensitive. Indicating the cultivar name on the packaging was important to white Gauteng and black Kwa-Zulu Natal consumers. These consumers gave the highest indication of familiarity with most of the cultivars studied (Table 5, Paper 1) and this probably is the reason why they want cultivar names indicated on packaging. In addition, Van der Merwe (2013) also found that importance ratings given by white consumers associated with cultivar loyalty and cultivar name indication on the packaging. Consumers did not rate eating apples without peel as an important factor. However, black Kwa-Zulu Natal consumers rated eating an apple without the peel higher than the other consumer groups in possible correspondence with their higher

preference for soft ripe texture. Older consumers also rated peeling an apple before eating higher than young consumers, probably because older consumers find it more difficult biting off and chewing an apple (Pèneau *et al*., 2006).

Fresh fruit buyer and shop of apple purchase

The older consumer groups' indication that they buy fresh fruit themselves compared to young consumers who generally do not buy their own fruit could be as a result of the older consumers earning income and therefore being in charge of fruit purchases. However, most of the young black consumers are responsible for buying fresh fruits instead of their parents. The young group in our study are mainly students and the white and Indian students' most likely stay in campus residences and therefore do not cook nor buy food themselves. Black students however, might have stayed in dormitories where they had to buy food themselves. More female consumers buy fresh fruits compared to male consumers whose parents more often buy the fruit they consume. This is probably because females eat more fruits than males do and perhaps are also more informed about the health benefits of fruits. Baker and Wardle (2003) found that women eat more fruit and vegetables than men, with 3.5 servings per day for women compared with 2.5 servings for men. In addition, more women than men were knowledgeable about recommendations and health benefits of fruits and vegetables (Baker and Wardle, 2003). Pèneau *et al*. (2006) also reported that more males than females indicated that they do not consume apples regularly. Another reason for the observed gender difference in relation to fresh fruit buyer is probably because, generally more females than males are responsible for shopping for the household. Vermeulen and Biénabe (2010) assessed household shopping roles and found that the main shopper in the household for fresh fruits mostly comprised of the wife, mother or female partner (84%).

Black, young white Gauteng and young Indian Kwa-Zulu Natal consumers buy apples more from Pick 'n Pay than from the other shops listed in the study. However, older black Kwa-Zulu Natal consumers also buy apples from Shoprite as much as they buy from Pick 'n Pay while older white Gauteng consumers buy apples from Pick 'n Pay, Woolworths, Fruit & Veg and Spar comparably and more than from other shops. The older Indian Kwa-Zulu Natal consumers buy apples from Pick 'n Pay, Fruit & Veg and Checkers and they buy apples from Woolworths as much as they buy from Checkers. These ethnic purchasing patterns are likely the legacy of South Africa's apartheid government system. Although South Africa's

apartheid rules have been abolished and the Group Areas Act of 1950 (Act No. 41 of 1950) also rescinded, ethnic groups in South African cities, towns and rural areas still reside in generally homogenous neighbourhoods. Particular neighbourhoods, as well as shop outlets are generally characterised and favoured by consumers belonging to specific LSM groups with dispensable income increasing from LSM 1 (115.84 US dollars per month) to LSM 10 (2,350.01 US dollars per month) (Wortley and Tshwaedi, 2002; Bishop, 2012; Holborn, 2012). Although specific LSM groups are not solely characterised by a particular ethnic group, LSMs 1-6 are dominated by black consumers, whereas, LSMs 8-10 consist predominantly of white consumers (Wortley and Tshwaedi, 2002; Holborn, 2012). Woolworths and Checkers target consumers in the LSM 8-10 groups (Woolworths Holdings Limited, 2012; Shoprite Holdings Limited, 2014), while Spar and Fruit & Veg operates across the entire LSM market (Vermeulen and Biénabe, 2010; Integrated Report, 2014) explaining their preference among white and Indian consumers. Vermeulen and Biénabe (2010) reported that all LSM groups preferred Pick ‘n Pay and Fruit & Veg, LSMs 7 and 8 preferred Shoprite and Checkers, while LSM 9 and 10 preferred Woolworths for fresh fruit purchases. Pick ‘n Pay and Shoprite target consumers in the LSM 4-7 group (Pick ‘n Pay Annual Results, 2012; Shoprite Holdings Limited, 2014) possibly explaining why black consumers generally purchase apples from Pick ‘n Pay and older black Kwa-Zulu Natal consumers buy apples from Shoprite, as well. Although, most of the consumers in our study were students, the white and Indian consumers had the highest percentages of professionals and administrative staff, thus explaining their purchasing of apples from Woolworths, Fruit & Veg, Spar and Checkers in addition to Pick ‘n Pay. However, differential purchasing patterns are not unique to South Africa. For example, Thompson and Kidwell (1998) found differences in the clientele of two retail outlets, with one store being a specialty regional chain grocery store and the other, a local cooperative, both in Tucson, Arizona and also that the specialty store attracted relatively older shoppers with higher income and more graduate or professional degrees.

Conclusions

The study revealed that ethnic and age group as well as gender of consumers in Gauteng and Kwa-Zulu Natal provinces significantly affected their conceptual preference for apple eating quality and appearance as well as their cultivar, purchasing and consumption preferences. Generally, consumers’ conceptual preferences associated with their actual preference patterns

(Paper 1), suggesting that to a large extent, consumers are aware of the attributes that drive their eating preferences. These consumers are generally also aware of the cultivars that will provide them with their preferred apple eating quality attributes. However, this generally applies for familiar cultivars or for cultivars where the appearance provides a clear and consistent indication of taste attributes. However, consumers are unable to form association between appearance and eating quality for cultivars that they are not familiar with. It is clear that considerable marketing and informative effort would be needed to familiarise the majority of South African consumers with cultivars such as Fuji. Based on taste preferences, most South African consumers should like the eating quality of this cultivar, but since they are not familiar with it, they indicate a weak conceptual preference for it.

Our data also indicate that local marketers and distributors could target black and older consumers and supply the geographical location where these consumers are concentrated with sweet tasting cultivars such as Fuji, Topred and Golden Delicious and with full and striped red apples. Young white and young Indian consumers collectively are a target group for crisp, juicy, moderately sour and full green cultivars such as Granny Smith. The general preference of female consumers for 'Pink Lady®' suggests that marketers were able to build a positive gender-based brand for this cultivar. It would be interesting to in future determine whether current efforts to re-brand 'Sundowner' as 'Joya' among young, adventurous and fun-loving people have been equally successful. Although male consumers could generally be supplied with sweet tasting cultivars, it should be noted that female consumers are generally buying fruit for the entire household.

Wholesalers and retailers generally know that as apple fruit background colour turns yellow, demand for the fruit may generally decline, thereby affecting apple sales. The effect of background colour in relation to fruit eating quality and consumer preference is discussed in detail in Paper 4. Consumers who are familiar with apple cultivars are interested in cultivar name indication on packaging, therefore for shop outlets that target especially white consumers, cultivar names must be indicated on packaging. Price plays an important role in the purchase decision for older consumers as well as consumers in the lower LSM groups but supermarkets in South Africa, already take that into account.

Considering our data, to maximise sales, Pick 'n Pay should stock a wide range of apple cultivars. Shoprite should stock more sweet, crispy and juicy tasting cultivars while Woolworths, Fruit & Veg, Checkers and Spar should stock firm, moderately sour, as well as sweet tasting cultivars.

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Table 1 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual preference of sensory attributes.

Factor	DF	Pr > F
Consumer group	3	**<0.0001**
Gender	1	**0.0003**
Consumer group*Gender	3	**0.0003**
Age	1	**0.003**
Consumer group*Age	3	**0.0041**
Gender*Age	1	**0.034**
Consumer group*Gender*Age	3	0.2035
Consumer group*Gender(Consumer)	561	**<0.0001**
Sensory attributes	12	**<0.0001**
Consumer group*Sensory attributes	36	**<0.0001**
Gender*Sensory attributes	12	**<0.0001**
Consumer group*Gender*Sensory attributes	36	**0.0006**
Age*Sensory attributes	12	**<0.0001**
Consumer group*Age*Sensory attributes	36	**0.0003**
Gender*Age*Sensory attributes	12	0.6822
Consumer group*Gender*Age*Sensory attributes	36	**0.0248**

Table 2 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual preference of peel colour and colouring patterns.

Factor	DF	Pr > F
Consumer group	3	**0.0411**
Gender	1	0.5090
Consumer group*Gender	3	**0.0019**
Age	1	**0.0003**
Consumer group*Age	3	0.1083
Gender*Age	1	0.1043
Consumer group*Gender*Age	3	0.1437
Consumer group*Gender(Consumer)	561	**<0.0001**
Peel colour and colouring patterns	7	**<0.0001**
Consumer group*Peel colour and colouring patterns	21	**<0.0001**
Gender*Peel colour and colouring patterns	7	**0.0210**
Consumer group*Gender*Peel colour and colouring patterns	21	**0.0043**
Age*Peel colour and colouring patterns	7	**<0.0001**
Consumer group*Age*Peel colour and colouring patterns	21	**0.0005**
Gender*Age*Peel colour and colouring patterns	7	0.4261
Consumer group*Gender*Age*Peel colour and colouring patterns	21	0.9602

Table 3 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual preference for cultivar.

Factor	DF	Pr > F
Consumer group	3	**0.0013**
Gender	1	**0.0095**
Consumer group*Gender	3	0.0537
Age	1	0.1719
Consumer group*Age	3	**0.0012**
Gender*Age	1	0.1582
Consumer group*Gender*Age	3	0.8191
Consumer group*Gender(Consumer)	517	**<0.0001**
Cultivar preference	8	**<0.0001**
Consumer group*Cultivar preference	24	**<0.0001**
Gender*Cultivar preference	8	**0.006**
Consumer group*Gender*Cultivar preference	24	0.5783
Age*Cultivar preference	8	**<0.0001**
Consumer group*Age*Cultivar preference	24	**<0.0001**
Gender*Age*Cultivar preference	8	0.1322
Consumer group*Gender*Age*Cultivar preference	24	0.8802

Table 4 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual preference for importance of purchase and consumption factors.

Factor	DF	Pr > F
Consumer group	3	**<0.0001**
Gender	1	**0.0303**
Consumer group*Gender	3	0.3182
Age	1	**0.0178**
Consumer group*Age	3	**0.0018**
Gender*Age	1	0.1136
Consumer group*Gender*Age	3	0.1898
Consumer group*Gender(Consumer)	561	**<0.0001**
Purchase factors	7	**<0.0001**
Consumer group*Purchase and consumption factors	21	**<0.0001**
Gender*Purchase and consumption factors	7	0.0628
Consumer group*Gender*Purchase and consumption factors	21	0.7937
Age*Purchase and consumption factors	7	**<0.0001**
Consumer group*Age*Purchase and consumption factors	21	0.2056
Gender*Age*Purchase and consumption factors	7	0.5847
Consumer group*Gender*Age*Purchase and consumption factors	21	0.4744

Table 5 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual rating for fresh fruit buyer.

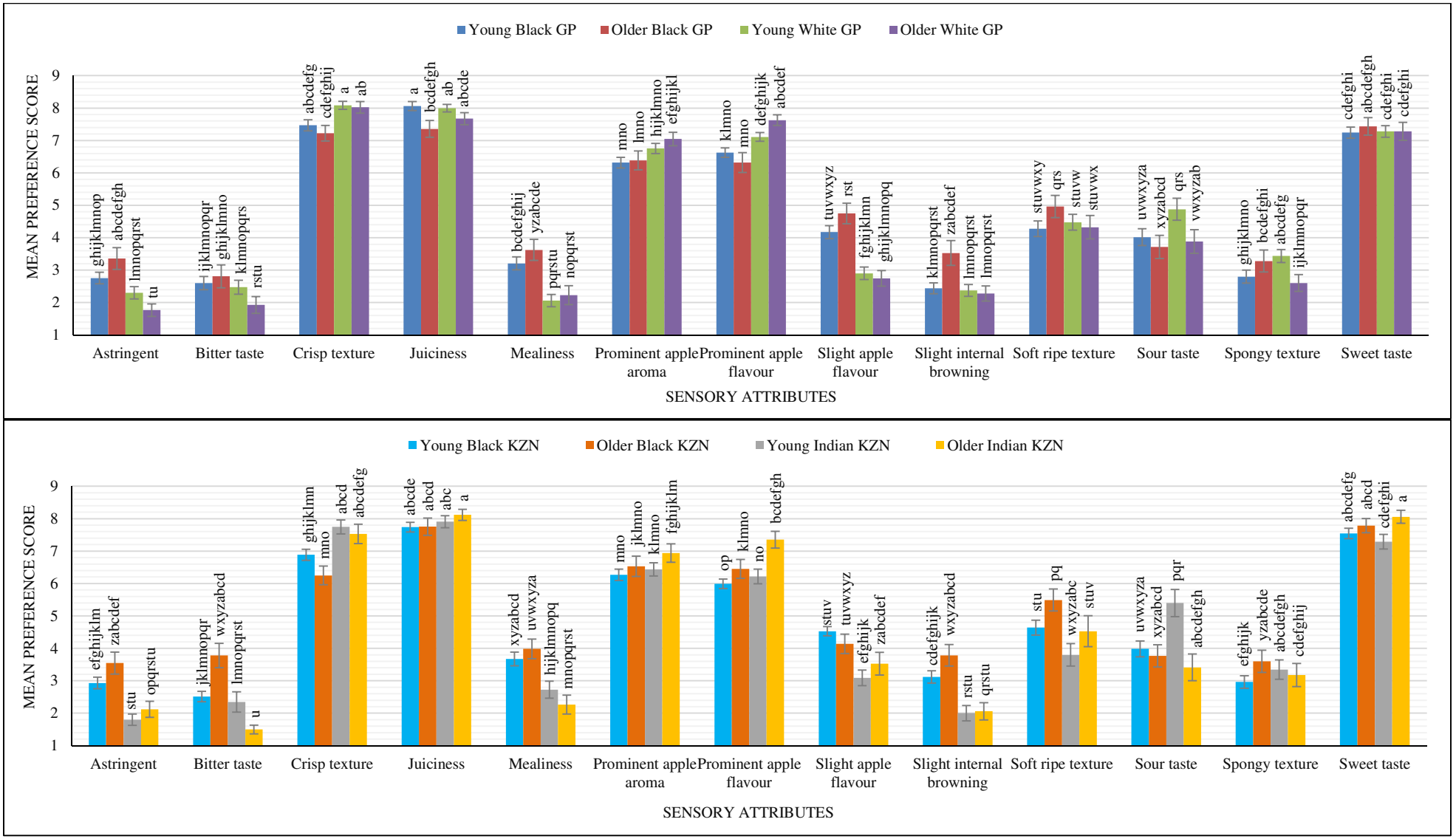
Factor	DF	Pr > F
Consumer group	3	0.9466
Gender	1	0.708
Consumer group*Gender	3	0.9251
Age	1	0.8689
Consumer group*Age	3	0.966
Gender*Age	1	0.8786
Consumer group*Gender*Age	3	0.9874
Consumer group*Gender(Consumer)	562	1
Fresh fruit buyer	3	**<0.0001**
Consumer group*Fresh fruit buyer	9	**<0.0001**
Gender*Fresh fruit buyer	3	**0.0136**
Consumer group*Gender*Fresh fruit buyer	9	0.0518
Age*Fresh fruit buyer	3	**<0.0001**
Consumer group*Age*Fresh fruit buyer	9	**0.0006**
Gender*Age*Fresh fruit buyer	3	0.9292
Consumer group*Gender*Age*Fresh fruit buyer	9	0.9896

Table 6 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual rating for shop of apple purchase.

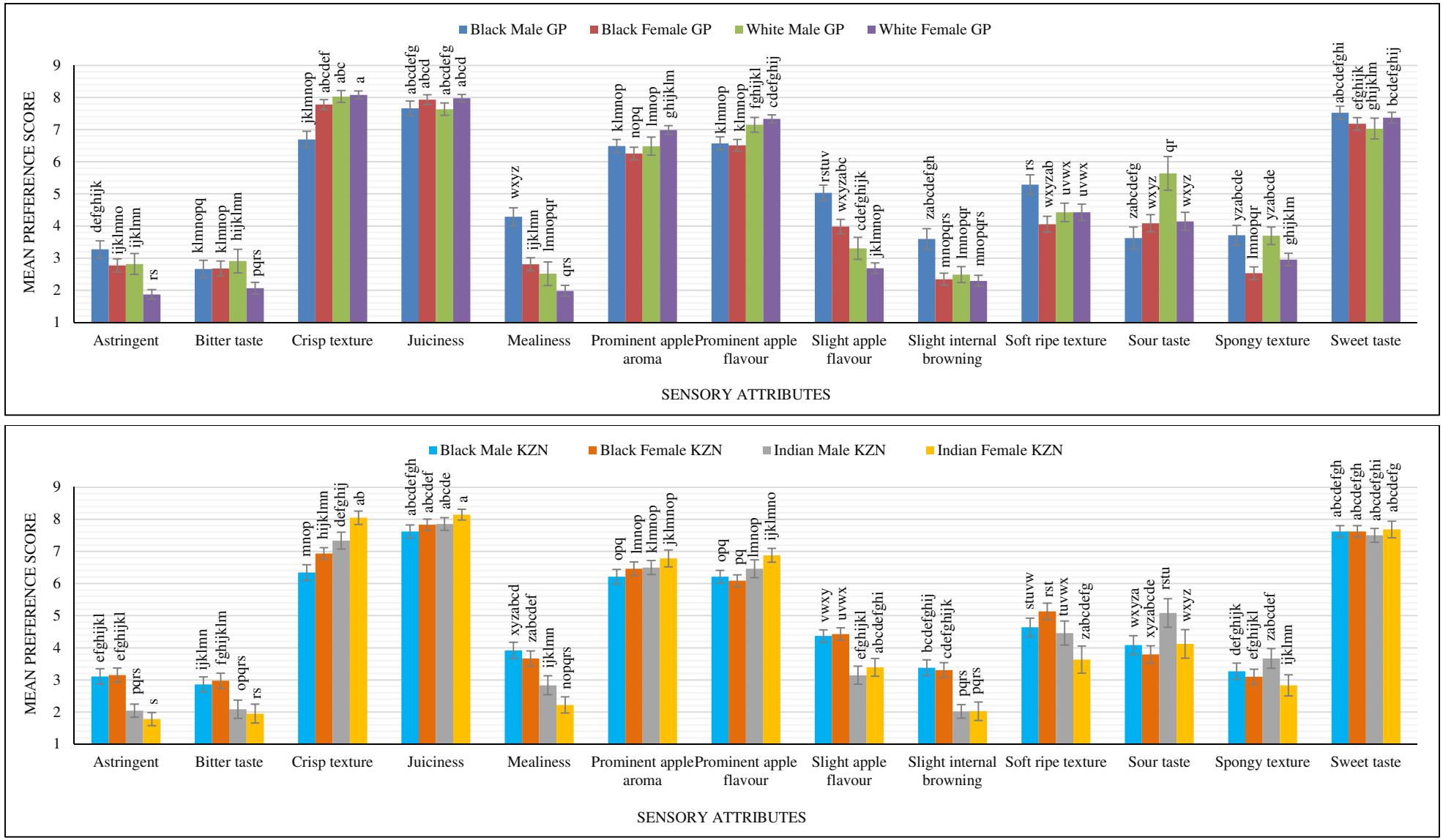
Factor	DF	Pr > F
Consumer group	3	**0.0002**
Gender	1	**0.0102**
Consumer group*Gender	3	0.4451
Age	1	**0.0256**
Consumer group*Age	3	**0.0032**
Gender*Age	1	**0.0199**
Consumer group*Gender*Age	3	0.0638
Consumer group*Gender(Consumer)	562	1
Shop of apple purchase	9	**<0.0001**
Consumer group*Shop of apple purchase	27	**<0.0001**
Gender*Shop of apple purchase	9	0.7176
Consumer group*Gender*Shop of apple purchase	27	0.3233
Age*Shop of apple purchase	9	0.8611
Consumer group*Age*Shop of apple purchase	27	**0.0386**
Gender*Age*Shop of apple purchase	9	0.0552
Consumer group*Gender*Age*Shop of apple purchase	27	0.5758

Table 7 ANOVA (Analysis of variance) table with main and interaction effects for area ethnic group, gender and age with conceptual rating for state of apple consumption.

Factor	DF	Pr > F
Consumer group	3	**0.0166**
Gender	1	0.1005
Consumer group*Gender	3	0.4521
Age	1	0.0794
Consumer group*Age	3	0.4138
Gender*Age	1	0.0751
Consumer group*Gender*Age	3	0.3851
Consumer group*Gender(Consumer)	562	1
State of apple consumption	4	**<0.0001**
Consumer group*State of apple consumption	12	**0.0039**
Gender*State of apple consumption	4	**0.0202**
Consumer group*Gender*State of apple consumption	12	0.9048
Age*State of apple consumption	4	**<0.0001**
Consumer group*Age*State of apple consumption	12	0.4138
Gender*Age*State of apple consumption	4	0.4305
Consumer group*Gender*Age*State of apple consumption	12	0.1239



Figures 1a & b Mean preference scores for apple sensory attributes as evaluated conceptually by consumers of different ethnic and age groups from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.



Figures 2a & b Mean preference scores for apple sensory attributes as evaluated conceptually by male and female consumers of different ethnic groups from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

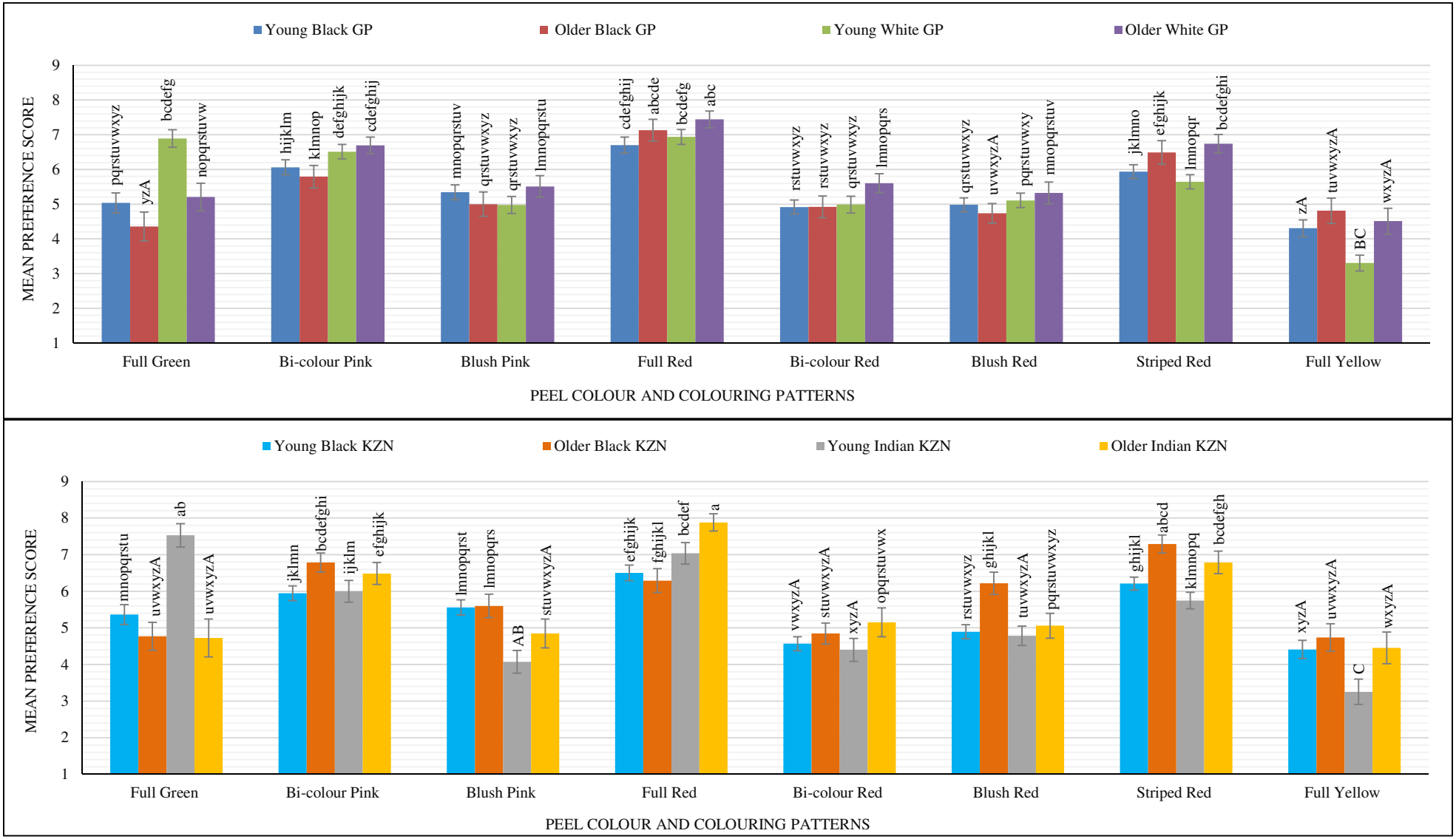


Figure 3a & b Mean preference scores for apple peel colours and colouring patterns as evaluated conceptually by black and white consumers aged between 18-25 (young) and 26+ (older) from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

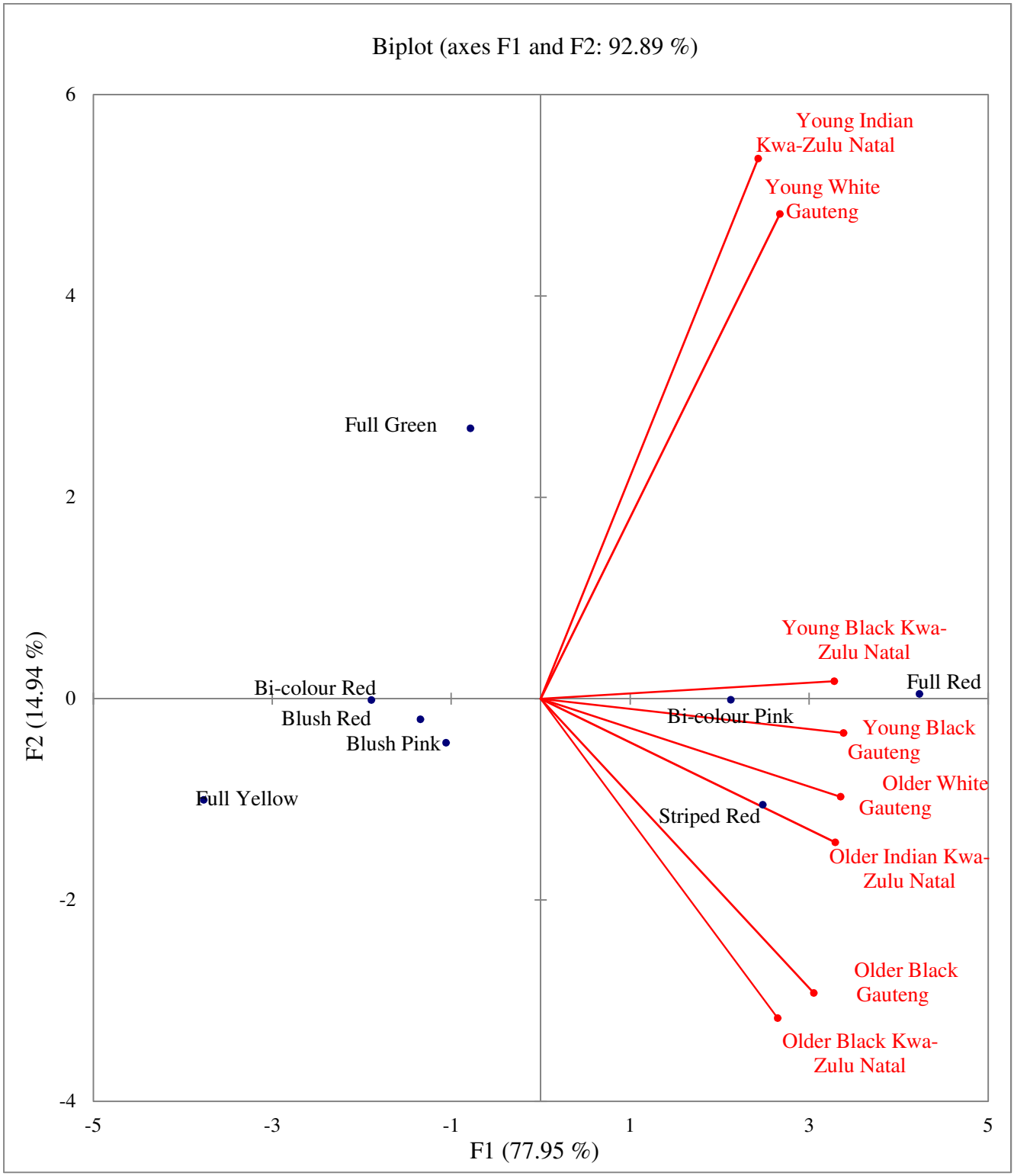


Figure 4 Principal component analysis bi-plot indicating the position of the consumer perceptual preference for apple colours and colouring patterns as evaluated by different ethnic (black, white and Indian) and age groups (young (18-25) and older (26+)) for Gauteng and Kwa-Zulu Natal Provinces, respectively.

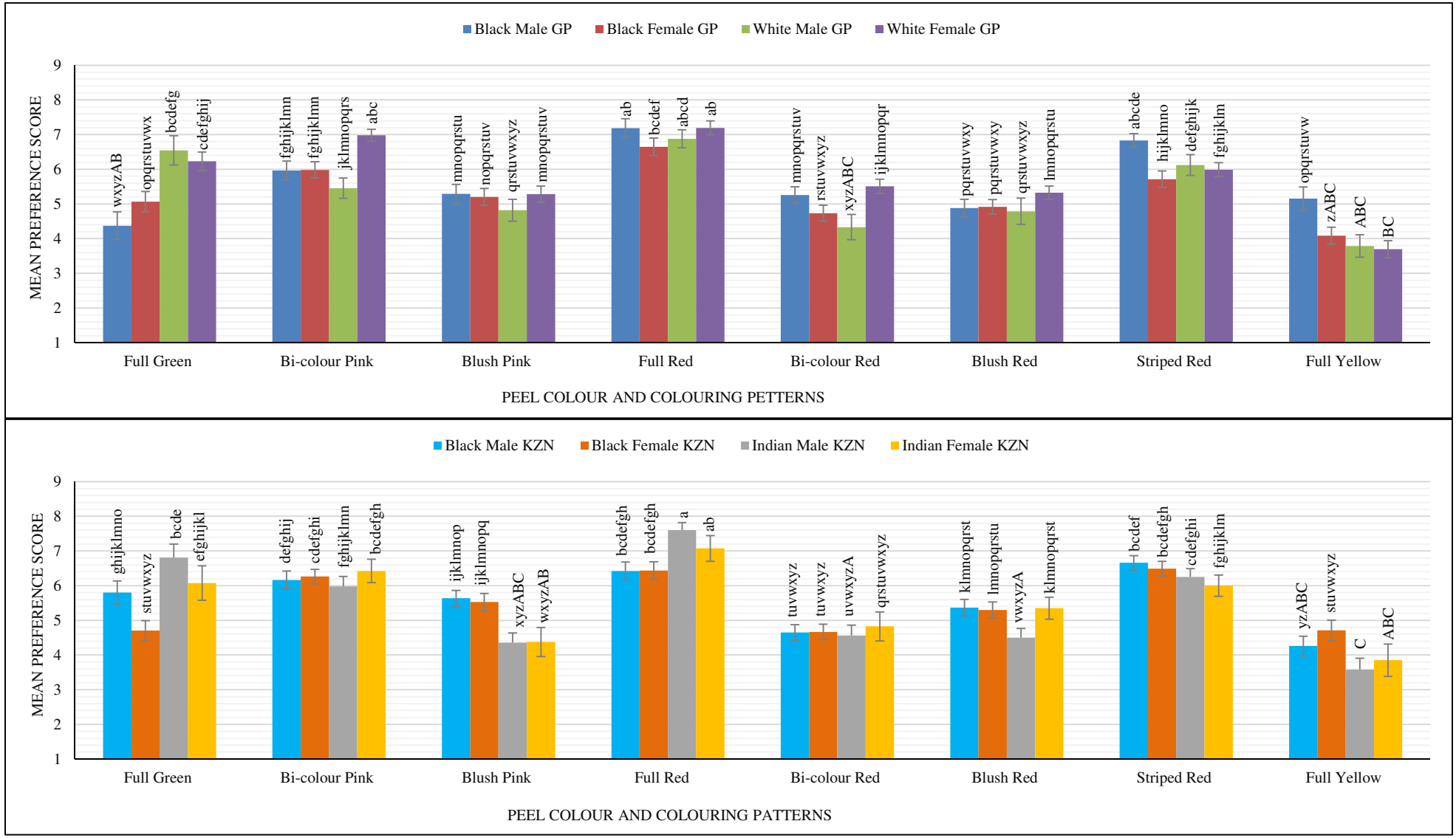


Figure 5a & b Mean preference scores for apple colours and colouring patterns as evaluated conceptually by male and female consumers of black and white ethnic groups, respectively from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

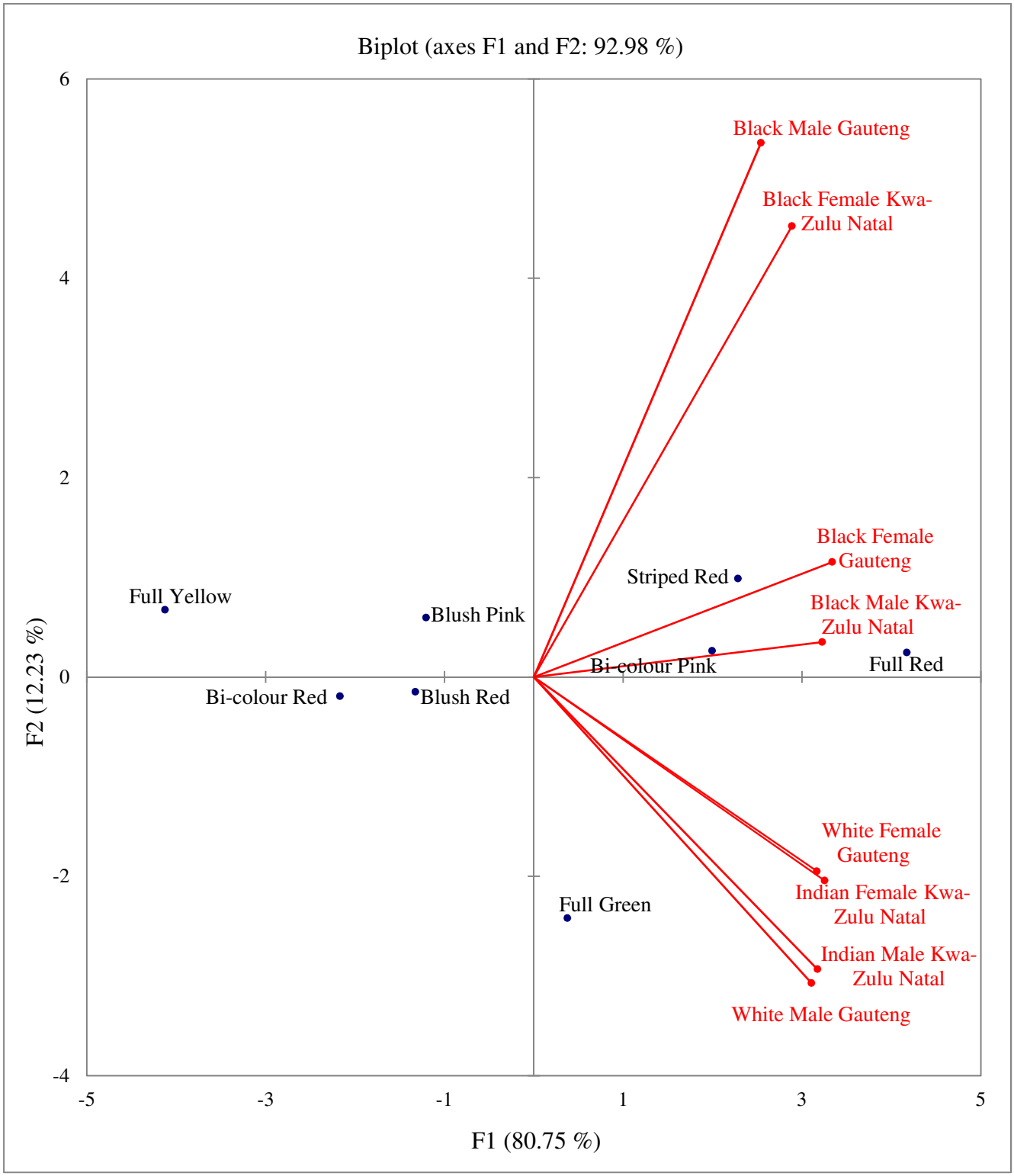


Figure 6 Principal component analysis bi-plot indicating the position of the consumer perceptual preference for apple colours and colouring patterns as evaluated by male and female consumers of black, white and Indian ethnic groups for Gauteng and Kwa-Zulu Natal Provinces, respectively.

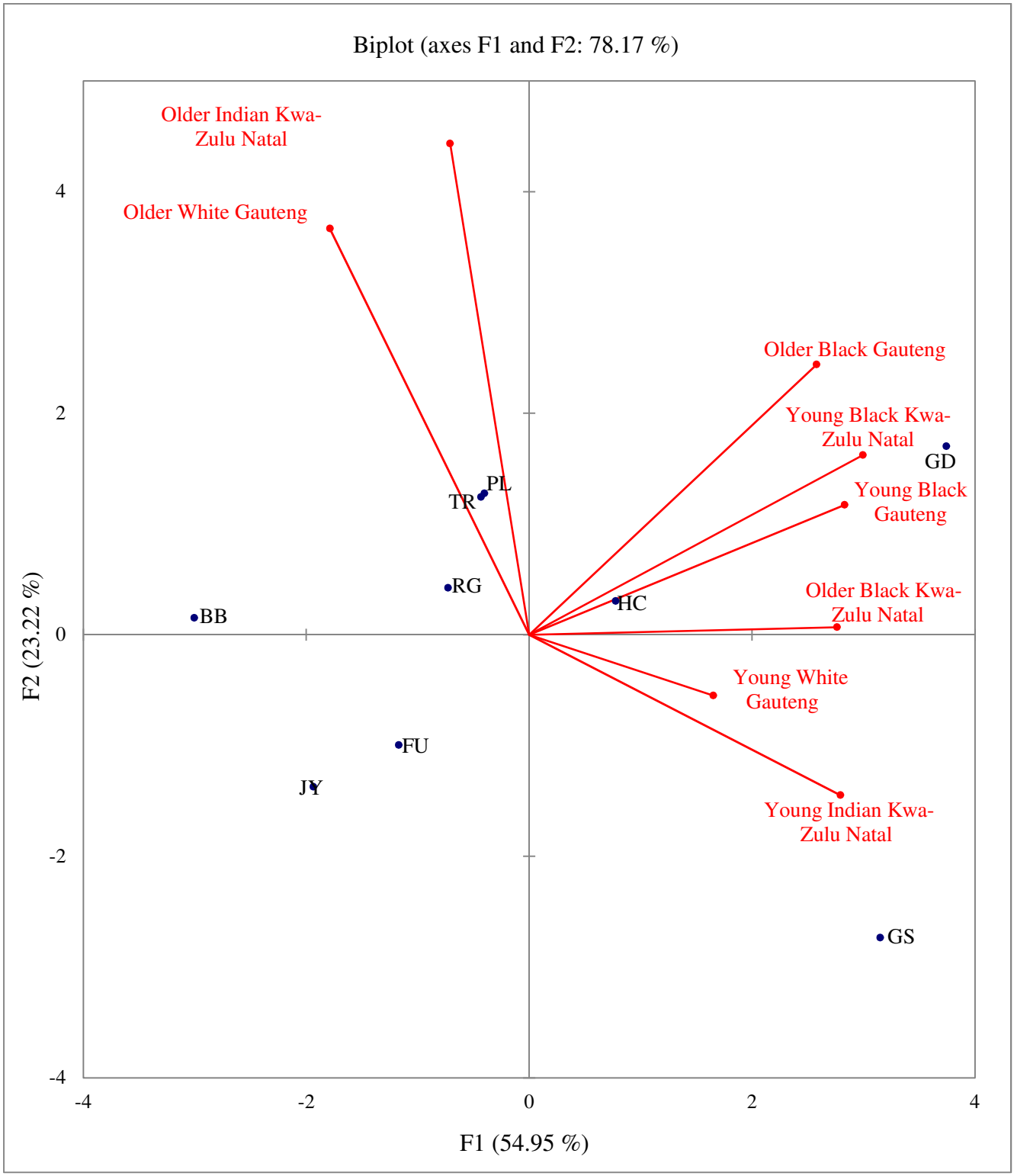
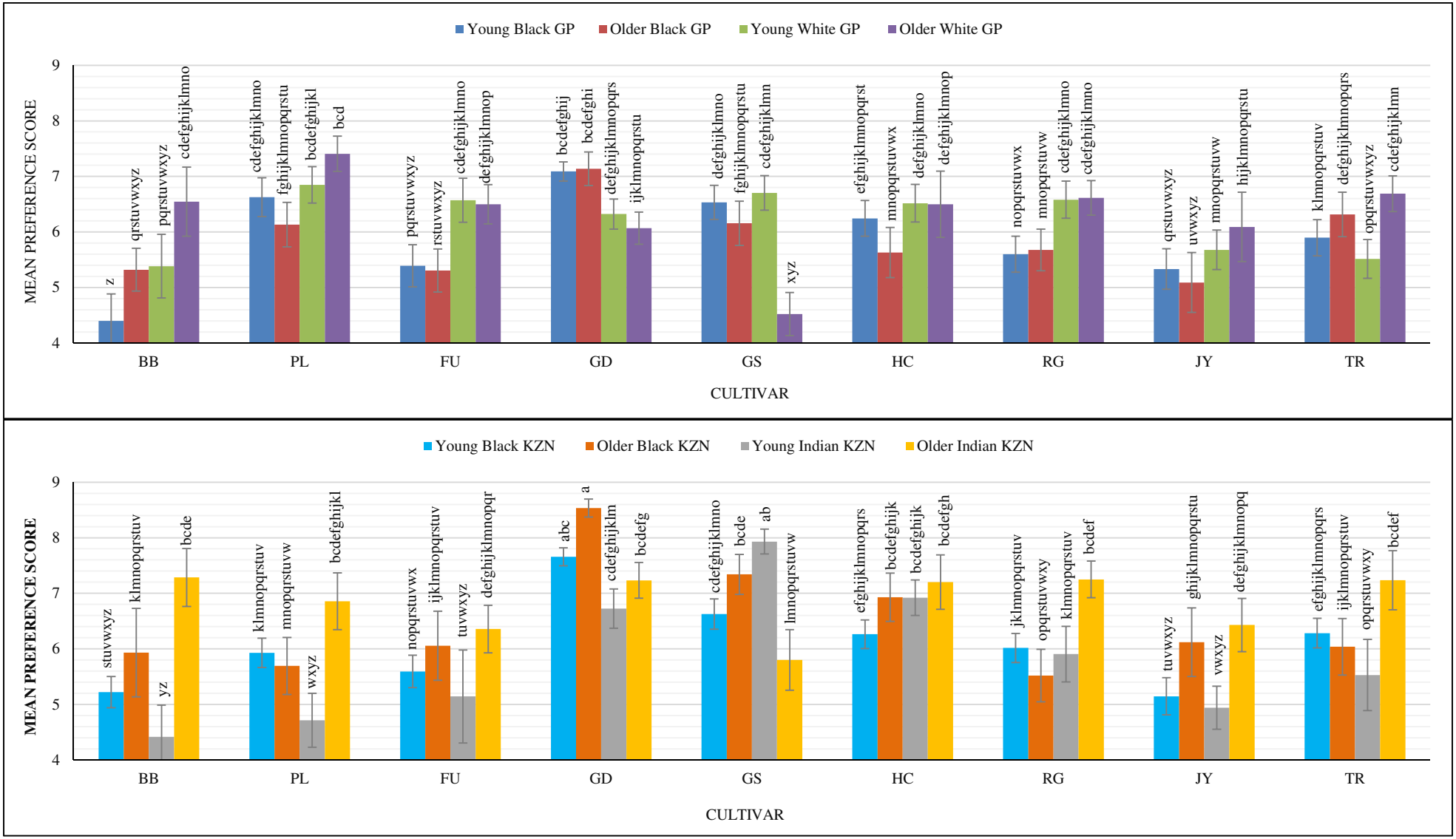


Figure 7 Principal component analysis bi-plot indicating the position of the consumer perceptual preference for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) as evaluated by different ethnic (black, white and Indian) and age groups (young (18-25) and older (26+)) for Gauteng and Kwa-Zulu Natal Provinces.



Figures 8a & b Mean preference scores for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) as evaluated conceptually by black and white consumers aged between 18-25 (young) and 26+ (older) from Gauteng (a) and Kwa-Zulu Natal (b) Provinces. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

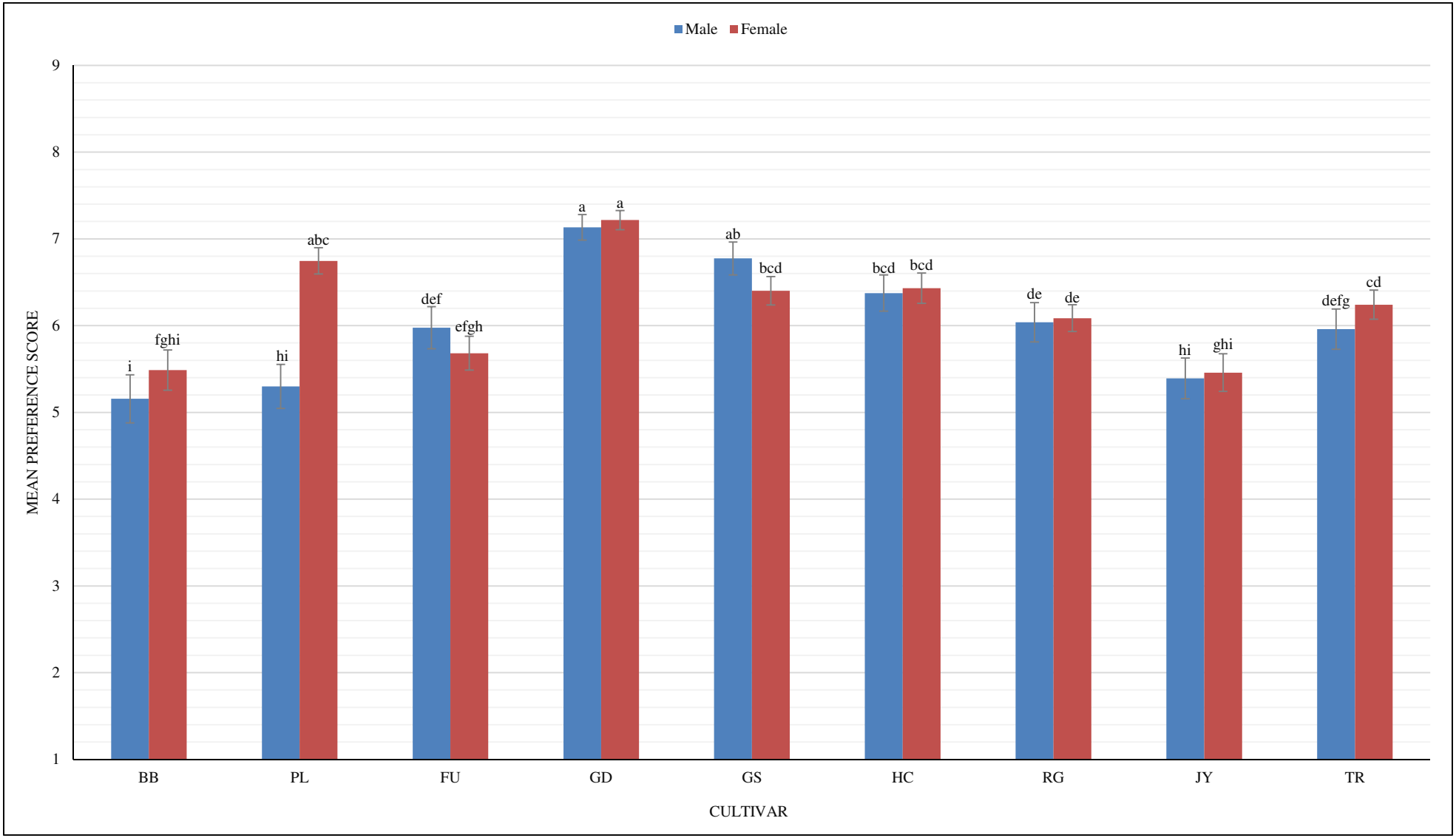


Figure 9 Mean preference scores for the nine apple cultivars, i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) as evaluated conceptually by male and female consumers. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

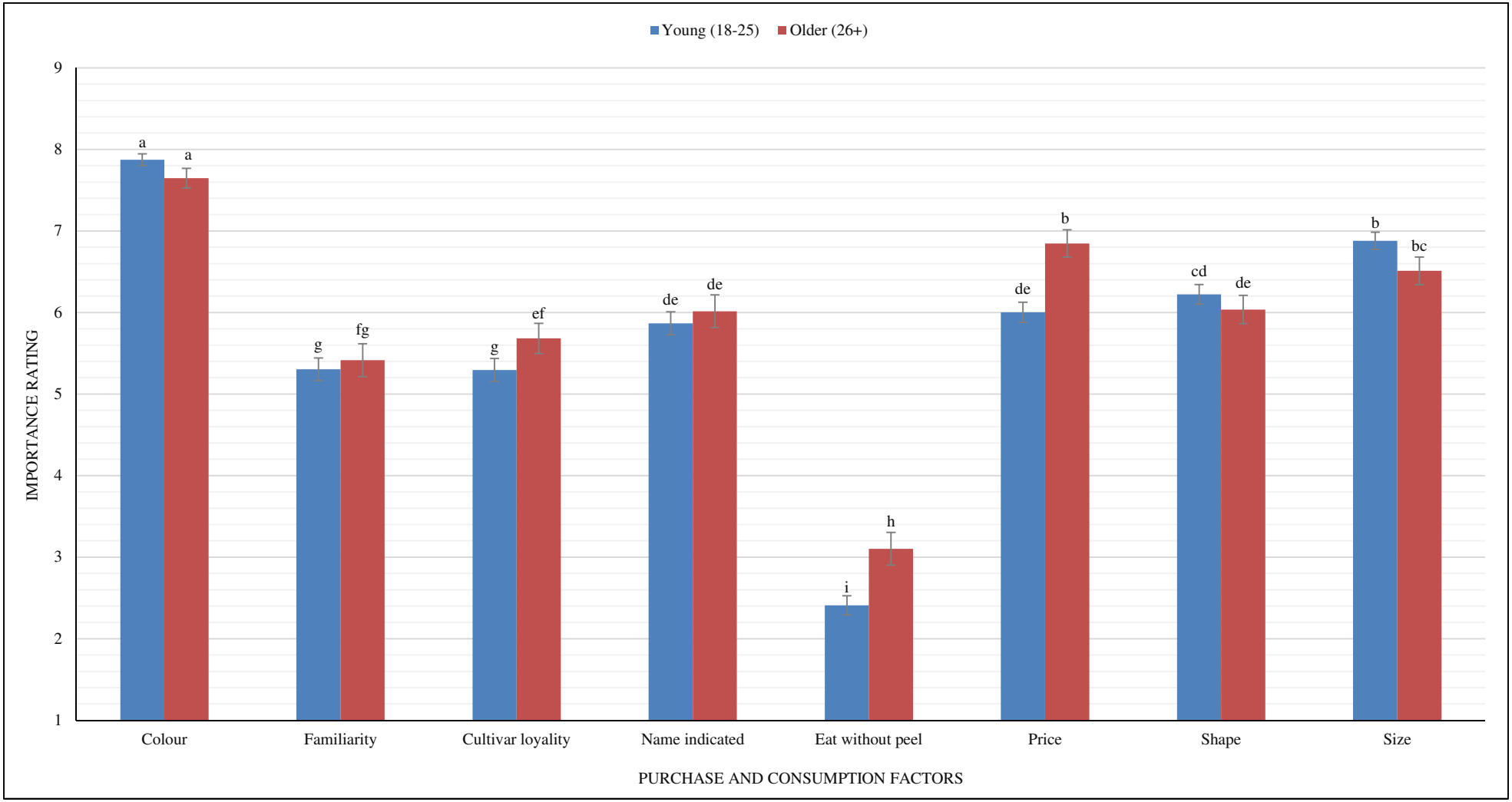


Figure 10 Importance ratings given to factors that influence purchase decisions for consumers of two different age groups, young (18-25) and older (26+), i.e., colour of the apple (colour), familiarity with cultivar (familiarity), loyalty to specific cultivars (cultivar loyalty), cultivar name indication on the packaging (name indicated), peeling an apple before eating it (eat without peel), price, shape and size of the apples. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

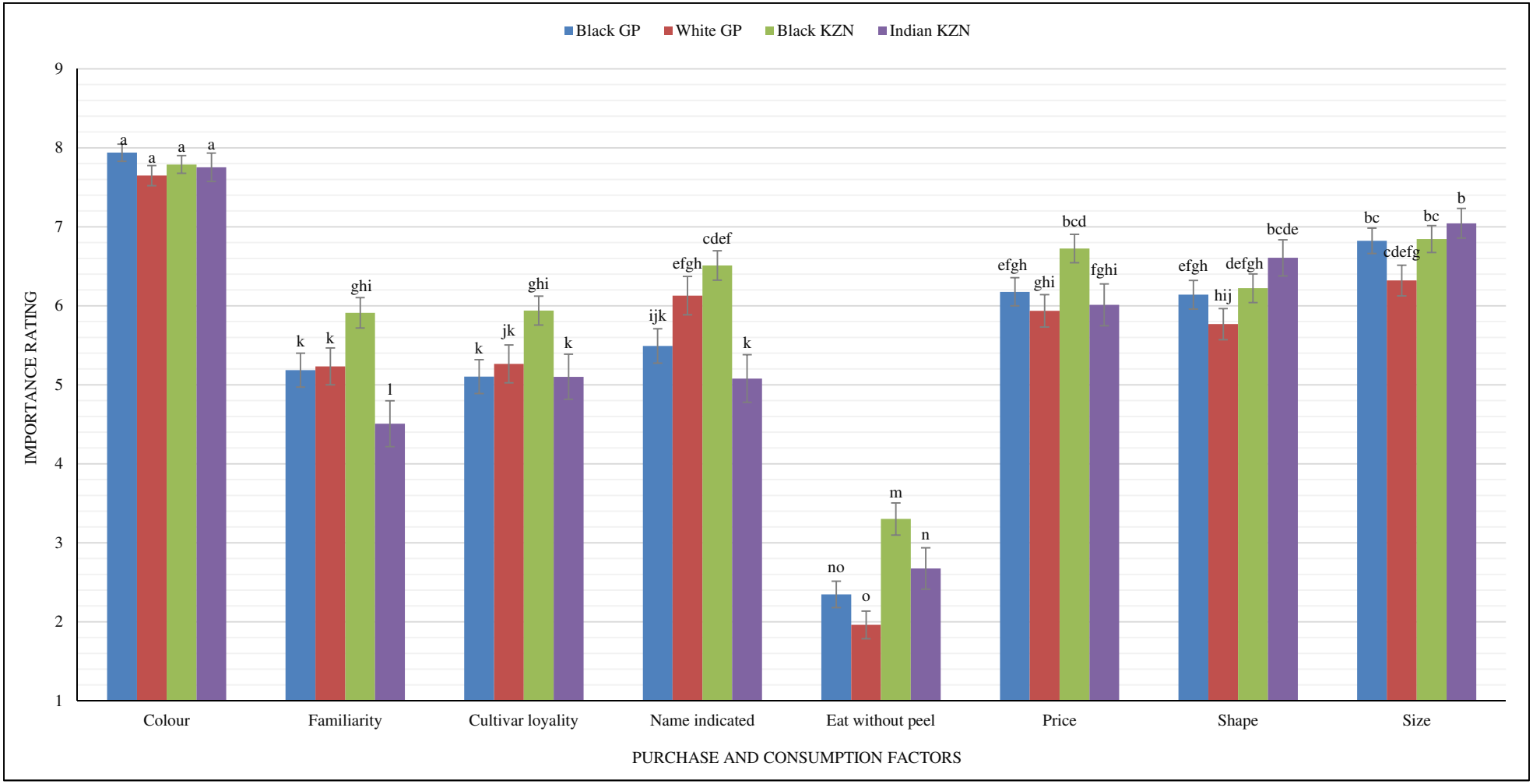


Figure 11 Importance ratings given to factors that influence purchase decisions for consumers of different ethnic groups from Gauteng and Kwa-Zulu Natal Provinces, respectively, i.e., colour of the apple (colour), familiarity with cultivar (familiarity), loyalty to specific cultivars (cultivar loyalty), cultivar name indication on the packaging (name indicated), peeling an apple before eating it (eat without peel), price, shape and size of the apples. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

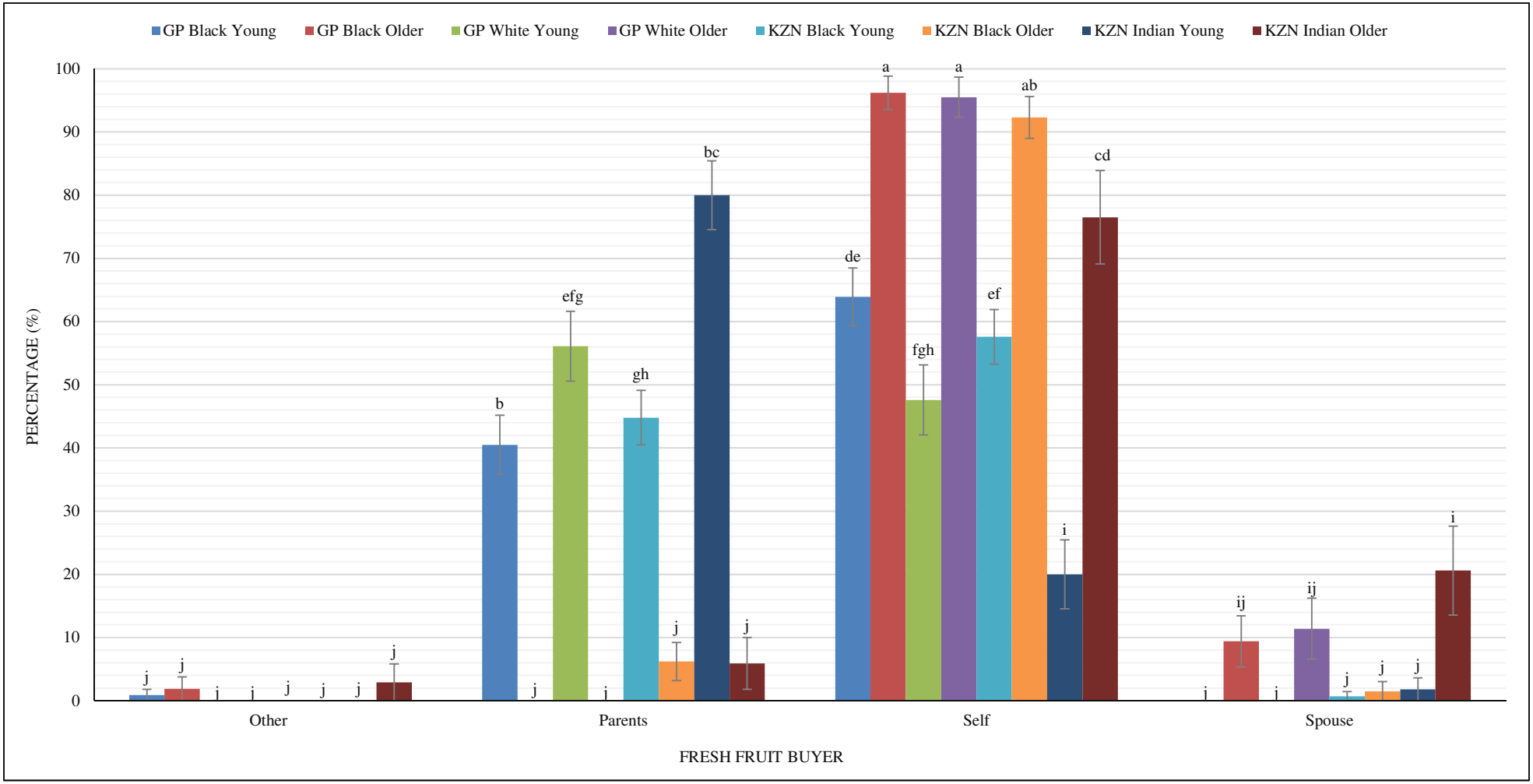


Figure 12 Ratings given for person responsible for buying fresh fruit by consumers of different ethnic (black, white, Indian) and age (young (18-25), older (26+)) groups from Gauteng and Kwa-Zulu Natal Provinces, respectively i.e., person responsible for fresh fruit buy other than parents, self or spouse (other), parents buy fresh fruit (parents), the consumer buys fresh fruit (self) and the consumer's spouse buys fresh fruit (spouse). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

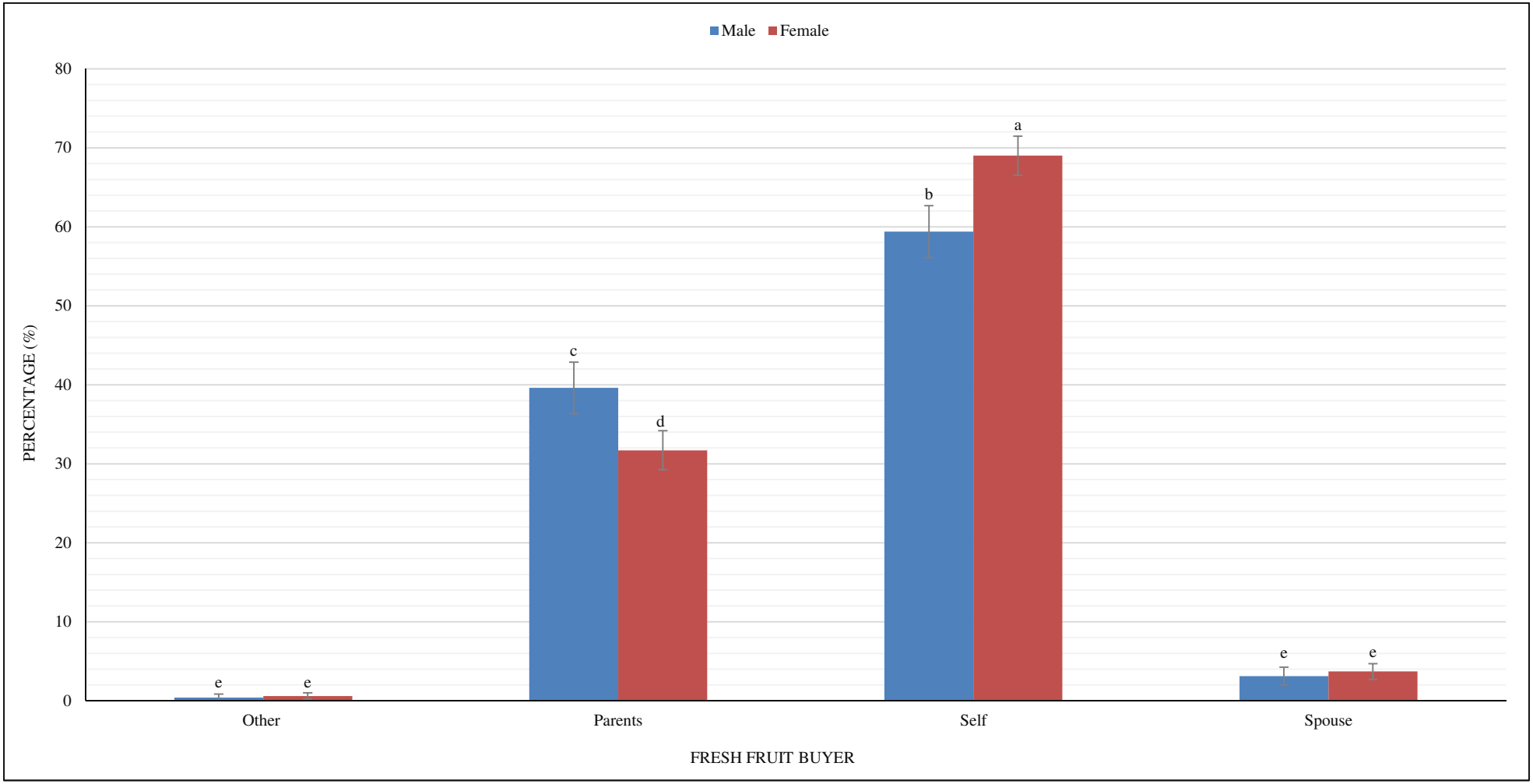


Figure 13 Ratings given for person responsible for buying fresh fruit by male and female consumers i.e., person responsible for fresh fruit buy other than parents, self or spouse (other), the consumer's parents buy fresh fruit (parents), the consumer buys fresh fruit (self) and the consumer's spouse buys fresh fruit (spouse). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

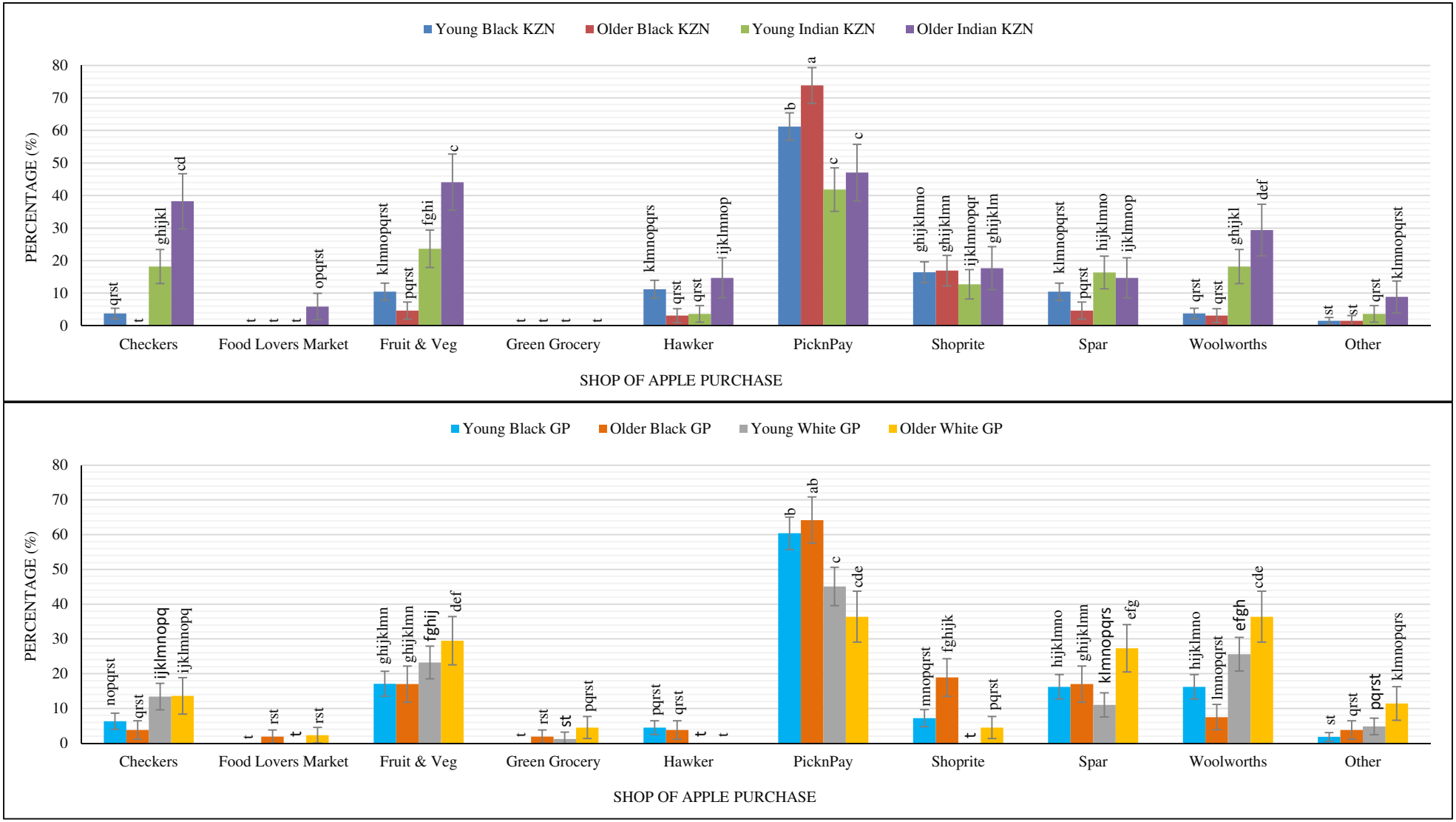


Figure 14a & b Ratings given for shop of apple purchase by consumers of different ethnic (black, white, Indian) and age (young (18-25), older (26+)) groups from Gauteng (a) Kwa-Zulu Natal (b) Provinces i.e., Checkers, Food Lovers Market, Fruit & Veg, Green Grocer, Hawker, PicknPay, Shoprite, Spar, Woolworths and Other. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

PAPER 3: SOUTH AFRICAN CONSUMER PREFERENCE CLUSTERS FOR APPLE EATING QUALITY AND APPEARANCE

Abstract

Employing the use of mean values for evaluating ethnic and age differences in apple eating quality and appearance preference provides an indication of general preference inclinations without really revealing the preference patterns of specific consumer groups. Therefore this study focused on identifying consumer clusters with distinct apple eating quality and appearance preferences by applying Ward's statistical clustering to consumer preference data for nine commercially available apple cultivars that were generated in Paper 1. Consumers with similar preferences segmented into three clusters based on their preferences for eating quality (eating quality clusters) and appearance (appearance clusters). Socio-demographic characteristics of consumers were related to their cluster membership in a posterior tabulation manner. Descriptive sensory analysis (DSA) data that were generated in Paper 1 were projected unto the eating quality clusters' preference dimension using principal component analysis (PCA) to identify drivers of liking. Eating quality clusters 1 and 2 (E1 and E2) with an overrepresentation of black Kwa-Zulu Natal and black Gauteng consumers, respectively, as well as older (26-61) consumers, liked sweet taste but disliked sour taste. E2 did not associate with sponginess while E1 did. E3 with an overrepresentation of young white Gauteng and young Indian Kwa-Zulu Natal consumers, liked sensory attributes relating to firmness and tolerated sour taste but disliked mealiness and sponginess. The three cluster solution based on consumers' preferences for apple appearance showed that appearance cluster 1 (A1) with an overrepresentation of black and older (26-61) consumers had a higher preference for red and green/yellow peel colour ('Topred', 'Honeycrisp', 'Royal Gala', 'Pink Lady®' and 'Golden Delicious') but disliked green peel colour ('Granny Smith'). A2 with an overrepresentation of white, Indian and young (18-25) consumers liked red and green peel colours ('Topred' and 'Granny Smith'), while A3, which constituted higher proportions of young white Gauteng and young Indian Kwa-Zulu Natal consumers liked green peel colour ('Granny Smith') but disliked red peel colour ('Topred'). Generally, consumers liked the appearance of the cultivars that associated with the eating quality attributes that they preferred and the preference patterns of respective clusters generally seem to correlate with consumers' actual eating quality and appearance preferences. However, when E3 data with its overrepresentation of white Gauteng and Indian Kwa-Zulu Natal consumers is extrapolated to

the actual population demographics of these provinces, Gauteng has twice as many black consumers compared to white consumers in E3 while Kwa-Zulu Natal has five times as many black consumers compared to Indian consumers in E3. Hence, despite the general preference within the population for sweet apples, it would be a mistake to limit the marketing of firm and sourer cultivars to white and Indian consumers. Compared to studies conducted in other countries, South African consumers generally exhibit similar preferences, thus either preferring sweetness with a tolerance for mealiness or firm, acidic cultivars with a dislike for mealiness.

Keywords *Malus x domestica* (Borkh.), cluster analysis, consumer preference, socio-demographic factors, principal component analysis.

Introduction

A substantial increase in the number of middle and high income consumers since 1994 (SAARF, 2012) and preference for fresh over canned fruit in the middle to upper income brackets (GAIN Report, 2012) has contributed to a rise in apple sales on South Africa's domestic market. Local sales currently amount to 27% of total production (HORTGRO, 2015). The already growing local market share could be further enhanced, thereby increasing profitability, if marketers and distributors could target apple cultivars at the consumer groups who are more likely to purchase it. Therefore, there is a need to have a clear understanding of the preferences of consumer groups on the local market. South Africa is made up of nine different metropolitan regions characterised by different ethnic and age groups (STATSSA, 2013). However, the only study that investigated the preference of local consumers for apple eating quality and appearance focused on the different ethnic and age groups in the Western Cape region (Van der Merwe, 2013). Consumer preferences for apple eating quality and appearance in other Metropolitan regions of South Africa are not known and whether the preferences of the Western Cape consumer groups will be similar or different from consumer groups in other Metropolitan regions is also not known.

Consumers of different ethnic and age groups in Gauteng and Kwa-Zulu Natal provinces differed in their overall preference patterns for apple quality and also in terms of factors that

influence their purchase decisions (Papers 1 and 2). Black and older consumers generally preferred sweet tasting apples while young white Gauteng and young Indian Kwa-Zulu Natal consumers associated more with textural attributes such as crispness, crunchiness, hardness and juiciness. In terms of actual appearance liking, young consumers preferred the appearance of 'Granny Smith' compared to older consumers. The conceptual preference of young white Gauteng and young Indian Kwa-Zulu Natal consumers for peel colour and colouring patterns was for green peel colour, while black and older consumers disliked green, but preferred full red, striped red and bi-colour pink peel colour.

Although ethnic and age differences in apple eating quality and appearance are of great significance, mean values only give an indication of general preference tendencies without necessarily revealing the preference patterns of particular consumer groups (Carbonell *et al*., 2008). In addition, consumers' preference for apple eating quality and appearance tend to differ and preference differences within the same ethnic group could be so large that similarities in preferences of consumers from different groups may not be avoided (Jaeger *et al.*, 1998; Harker *et al.*, 2003). The identification of groups of consumers with similar preference patterns can be achieved by applying cluster analysis to preference data (Vigneau *et al*., 2001; Santa Cruz *et al*., 2002; Jaeger *et al*., 2003) or by cluster analysis of mean centred preference data (Carbonell *et al*., 2008; Van der Merwe, 2013). A number of European studies have identified three preference clusters for apple eating consumers, i.e. those that prefer sweet apples with a slight tolerance for mealiness or crisp, hard and acid apples with a dislike for sweetness or mealiness and also those that prefer firm, juicy apples with moderate acidity (Daillant-Spinnler *et al*., 1996; Carbonell *et al*., 2008; Bonany *et al*., 2014). Three clusters that differed in their eating quality and appearance preferences were also identified in the Western Cape region (Van der Merwe, 2013). Cluster 1, which constituted the largest proportion of white and the youngest (18-25) consumers liked firmness, tolerated sour taste, disliked sweet taste and mealiness and preferred green and pink bi-coloured apples. Cluster 2, which constituted mostly white consumers in the 26-35 years age group, liked sour taste, apple flavour and preferred green/yellow and red striped peel colours, while cluster 3, which constituted the largest proportion of black and coloured consumers with a good representation of consumers in all the three age groups (18-25, 26-35 and 36+), disliked sour taste and preferred red peel colour. However, whether similar consumer groups exist in other metropolitan regions of South Africa, as well as how socio-

demographic characteristics, socio-economic status and apple consumption patterns relate to various clusters, are not known.

In view of the above, data generated in Papers 1 and 2 were analysed to gain a better understanding of preferences of consumers in the Gauteng and Kwa-Zulu Natal provinces of South Africa. Therefore, the aims of this research were to: 1) Ascertain the sensory attributes that drive the apple preferences of consumer clusters in the Gauteng and Kwa-Zulu Natal provinces; 2) determine the relative size of these clusters; 3) determine whether cluster differences can be related to socio-demographic differences and 4) envisage how socio-demographic characteristics could be used in order to reorganise cultivar distribution to the market segment most likely to purchase it.

Materials and methods

Sensory and consumer analysis

The plant material that were used, the descriptive sensory analysis (DSA), consumer recruitment and consumer preference analysis that were carried out are reported in Paper 1 and will not be reported here. The young age group ranged from 18 to 25 and the older age group ranged from 26 to 61. However, a majority of the older group consumers were found in ages 26 to 41 and will be reported as 26+.

Statistical procedures

Refer to Paper 1 for a description of the analysis of variance (ANOVA) that was applied to data generated by DSA.

Consumer preference data generated in Papers 1 and 2 were subjected to cluster analysis by Wards' clustering method, using XLSTAT software (Addinsoft, Version 2013.5.07, New York, USA). The preference data were double centred (i.e. row and column centring) due to consumer differences in scale usage and clustering was conducted on the residual preference data (Martens *et al*., 2005). A hierarchical clustering method was performed in which the software automatically detected the number of clusters that resulted in the best statistical fit. Consumer socio-demographic data were related to the different clusters in a posterior

tabulation manner – a method in which the preference data are analysed first and the results then related to the consumer data (Næs *et al.*, 2010). Similar analyses were performed on the consumers' appearance preference data. Consumers' cluster membership for the clusters based on eating quality preferences were furthermore related to importance ratings given to purchase factors and the preference for conceptual apple eating quality and consumers' cluster membership for the clusters based on appearance preferences were related to importance ratings given to purchase factors and the preference appearance attributes, respectively, by the use of Partial least squares (PLS) regression (consumers' importance ratings as X-variables and age or consumer group as Y-variable) (Johansen *et al.*, 2010). Dummy variables were created for the cluster membership and used as the categorical variables in the PLS model (Næs *et al.*, 2010). In order to compare consumers' preference for eating quality with their preference for appearance, their cluster membership (based on their preference for eating quality) was projected onto their cluster membership (based on their preference for appearance) with PCA.

Results

For the purpose of this part of the study and to avoid the use of ambiguous terms for reporting, "preference for overall eating quality" indicates consumers' degree of liking for the flavour, taste and texture of the fruit, whereas "preference for appearance" indicates how consumers liked the overall colour and shape of the fruit. In order to be concise, the terms "Eating cluster 1" (E1), "Eating cluster 2" (E2) and "Eating cluster 3" (E3) will be used for the clusters that were obtained by consumers' responses to eating quality. Clusters that were obtained by consumers' responses to appearance will be referred to as "Appearance cluster 1" (A1), "Appearance cluster 2" (A2) and "Appearance cluster 3" (A3).

The differences in socio-demographic composition between clusters (eating quality and appearance clusters) were compared and expressed as a percentage of the total group for each factor [i.e. age, gender, education, employment status, purchasing of fruit (fruit buy), purchasing of apples (apple buy) and apple consumption] per consumer group. For the sake of brevity and readability, only the most important actual preference data and socio-demographic differences between eating quality and appearance clusters will be reported.

Conceptual preference data for sensory and appearance attributes with importance ratings of purchase factors will be reported for eating quality and appearance clusters, respectively.

Sample attributes

DSA of all samples are reported and discussed in Paper 1 and will not be reported in this chapter.

Clustering based on preference for eating quality

Clustering of consumers' preference for overall eating quality resulted in a three cluster solution with the highest statistical fit.

Cluster composition and socio-demographic data

E1, E2 and E3 constituted 38%, 37% and 25% of the total consumer group, respectively (Table 1). E1 constituted the largest proportion of black Kwa-Zulu Natal and older consumers. The young white Gauteng and young Indian Kwa-Zulu Natal consumers were over-represented in E3 but underrepresented in E1 and E2, respectively. Young consumers were also underrepresented in E1. The younger consumers were generally well represented in E3, except for young black Kwa-Zulu Natal consumers. Black Gauteng consumers were well represented in E2, while black Gauteng and black Kwa-Zulu Natal consumers were underrepresented in E3. Older Indian consumers had the highest representation in E2. Male and female consumers were fairly equally represented between clusters. The PLS plot indicates that E3 associates with white, Indian and young (18-25) consumers (Fig. 1). E1 and E2 are located more towards the middle of the plot and associations are less clear, although it seems that black Kwa-Zulu Natal and black Gauteng consumers are more associated with E1 and E2, respectively.

E1 constituted the largest proportion of the 5% of consumers who did not obtain a final school year qualification (Table 1; Fig. 1). Consumers who did not obtain a final school year qualification were underrepresented in E2 and E3. Consumers, who had passed matric or who obtained a qualification from a tertiary institute were fairly equally represented in the different groups. Consumers who did other jobs than those specified were overrepresented in

E1 and also associated with E1 on the PLS plot (Fig. 1). These consumers, as well as professionals and administrative staff were underrepresented in E3. Professionals, administrative and technical staff were overrepresented in E2. Administrative staff was overrepresented in E1. E3 associated on the PLS plot with students. E2 associated with technical and administrative staff, as well as professionals on the PLS plot (Fig. 1). Less frequent apple consumers were more prevalent in E3 while there was an over representation of frequent apple buyers and consumers in E1.

Consumer preference data

The first (PC 1) and second (PC 2) principal components accounted for 51.1% and 20.2%, respectively, of the variability in responses of the eating quality clusters (Fig. 2). Juiciness, crunchiness, crispness, hardness, sour taste, as well as mealiness and sponginess explained more of the variance in the data on PC 1 while astringency, apple aroma and bitterness drove the variation on PC 2. Cultivars separated all along PC1 with 'Granny Smith' versus 'Royal Gala' and 'Golden Delicious' at the extreme ends. PC 2 mostly separated 'Topred' from the other cultivars, especially 'Braeburn'.

E3 separated from E1 and E2 on PC 1 (Fig. 2). The preferences of E1 correlated positively with sweet taste (r=0.90; P=0.001) and sponginess (r=0.83; P=0.005), but negatively with sour taste (r=−0.88, P=0.002) indicating a degree of liking for cultivars such as Golden Delicious and Topred. The preferences of E2 correlated positively with sweet taste (r=0.75; P=0.021), but negatively with sour taste (r=−0.75; P=0.020). However, there was no significant correlation between E2 and sponginess (P>0.05). This tendency of E2 liking sweet taste is clearly illustrated in Fig. 2 with E2 being associated with Fuji on PC 1. Crispness (r=0.94; P=0.001), crunchiness (r=0.91; P=0.001), hardness (r=0.89; P=0.001), juiciness (r=0.84; P=0.005) and sour taste (r=0.81, P=0.009) were the strongest drivers of liking for E3, who disliked mealiness (r=−0.91; P=0.001) and sponginess (r=−0.77; P=0.016). These correlations could all be driven by these consumers' liking of 'Granny Smith'.

E1 consumers preferred Topred and Fuji significantly more than other cultivars except for Golden Delicious, followed by Joya™ and Royal Gala, while Granny Smith and Honeycrisp received the lowest liking scores (Fig. 3). E1 consumers indicated appreciable preference for

all the nine apple cultivars used in the study with average liking scores of between 5.9 (GS) and 7.1 (TR), illustrating general acceptability of eating quality across all cultivars (Fig. 3). E2 gave higher preference scores for 'Fuji', 'Honeycrisp' and 'Topred', but disliked 'Braeburn' and 'Granny Smith' in particular. E3 indicated significantly highest preference score for 'Granny Smith' followed by 'Braeburn', but disliked 'Royal Gala' and also gave low scores for 'Golden Delicious' and 'Topred'.

The residuals (computed from double mean centring) of the cultivar liking scores for the eating quality clusters showed that cluster segregation was driven by a much greater liking of E3 consumers for 'Granny Smith', and to lesser extent 'Braeburn' and 'Pink Lady', and their much lesser liking for 'Royal Gala', 'Topred' and 'Golden Delicious' (Fig. 4). E2 segregated from the other clusters in their much lower preference for 'Granny Smith', a slightly lower preference for 'Braeburn' and a slightly higher preference for 'Fuji'. Relative to the other clusters, E1 consumers indicated a slightly lower preference for 'Honeycrisp' and a slight preference for 'Golden Delicious'. 'Joya™' was the only cultivar that did not segregate between clusters in terms of residual scores, although E2 and E3 consumers gave it lower average scores than E1 consumers.

Clustering based on preference for appearance

Clustering on consumers' preference for appearance resulted in a three cluster solution with the highest statistical fit.

Cluster composition and socio-demographic data

A1, A2 and A3 constituted 43%, 38% and 19% of the total consumer group, respectively (Table 2). A1 constituted the largest proportion of black and older consumers, with older black Kwa-Zulu Natal consumers being overrepresented in particular. White Gauteng and Indian Kwa-Zulu Natal consumers were over-represented and black Kwa-Zulu Natal consumers underrepresented in A2. Young white Gauteng and young Indian Kwa-Zulu Natal consumers were underrepresented in A1 and overrepresented in A3. Older consumers of all ethnic groups were underrepresented in A3. Male and female consumers were fairly equally represented between groups, except for an underrepresentation of males in A2. The PLS plot

indicates that A1 associates with black Kwa-Zulu Natal, A2 with white and Indian consumers and A3 with black Gauteng and young (18-25) consumers (Fig. 5).

A1 constituted the largest proportion of the 5% of consumers who did not obtain a final school year qualification (Table 2; Fig. 5). Consumers who did not obtain a final school year qualification were underrepresented in A2. Consumers who had passed matric or who obtained a qualification from a tertiary institute were fairly equally represented in the different groups. Consumers who did other jobs than those specified were overrepresented in A1 and also associated with A1 on the PLS plot (Fig. 5). These consumers were underrepresented in A2 and together with professionals and administrative staff also underrepresented in A3. Professionals, administrative and technical staff were overrepresented in A1. Students were slightly underrepresented in A1 (Table 2) and associated with A3 on the PLS plot. Frequent apple buyers and consumers were overrepresented in A1 and also associated with A1 on the PLS plot. Less frequent apple consumers were well represented in A2.

Consumer preference data

The first (PC 1) and second (PC 2) principal components accounted for 52.7% and 32.8%, respectively, of the variability in responses of the appearance clusters (Fig. 6). A3 separated from A1 on PC 1; however, the separation on PC 2 is less clear. On PC 1, A3's preferences for appearance associated strongly with 'Granny Smith', and to a lesser extent with the rest of the cultivars. A2's preference for appearance was in close association with 'Topred' and further sample-liking of appearance associations for A2 are less clear. However, A2 consumers seemed not to like the appearance of 'Fuji' and 'Braeburn'. A1's preference for appearance was in close association with most of the cultivars, except for 'Fuji' and 'Braeburn' on the left side of PC 1 as well as 'Granny Smith' on the far right of PC 1.

According to the ANOVA results (Fig. 7), A1 consumers had high appearance acceptability scores for most cultivars, except for Granny Smith, which had a mean hedonic score of 3.7. These results show that this group of consumers find most apple appearance patterns acceptable except for a low acceptability of the green appearance of 'Granny Smith'. A2 consumers liked the appearance of 'Topred' and 'Granny Smith' significantly more than that

of the other cultivars with a mean score of 7.5 and 7.4, respectively. This group of consumers furthermore illustrated high appearance liking scores for all other cultivars, except for 'Fuji' and 'Braeburn' which scored 4.7 and 4.9 respectively, for appearance liking. A3 consumers indicated a significantly higher and strong preference for the appearance of 'Granny Smith' and a dislike for 'Topred'. These consumers also gave a high preference score for 'Golden Delicious', which they preferred to all cultivars except 'Granny Smith'. Like A2 consumers, they also gave lower scores for 'Fuji' and 'Braeburn', but also 'Joya™'. Their scores for 'Royal Gala' and 'Honeycrisp' were intermediate.

The residuals for the cultivar liking scores for the appearance clusters showed that cluster segregation was driven by a much greater liking of A3 consumers for 'Granny Smith', and to lesser extent 'Golden Delicious', and much lower liking of 'Topred' (Fig. 8). A3 consumers also segregated from the other clusters in having a lower liking for 'Royal Gala' and 'Joya™'. A2 segregated from A1 in their significant preference for 'Granny Smith' and from both other clusters in their slightly higher preference of 'Topred' and their lower preference for 'Golden Delicious', 'Fuji' and 'Braeburn'. A1 consumers differed from the other clusters primarily in their dislike for 'Granny Smith' and to a lesser extent in their greater preference for 'Fuji' and 'Honeycrisp'. According to the residual data, 'Pink Lady' was the only cultivar which did not segregate significantly in preference between clusters.

The relation between preference for eating quality and appearance

Consumers' eating quality cluster membership was projected onto their appearance cluster membership (Fig. 9). The PCA bi-plot explained 75.4% of the variability in consumers' responses, with PC 1 and PC 2 accounting for 54.9% and 20.5%, respectively.

Granny Smith separated from the other cultivars on PC 1 while Fuji and Braeburn seemed to separate from other cultivars on PC 2. Predilection for 'Topred', 'Royal Gala', 'Golden Delicious', 'Joya' and 'Honeycrisp' associated positively with the preference of consumers in E1, E2 and A1. However, E1, E2 and A1 seemed to be negatively correlated with 'Granny Smith'. E3 associated positively with 'Braeburn' but negatively with 'Royal Gala', 'Golden Delicious' and 'Topred'. A2 associated positively with 'Royal Gala' but negatively with 'Fuji'. As principal component analysis was based on the correlation matrix, our results show

that E2 correlated positively with A1 (r=0.84; P=0.004) but had a negative correlation with A3 (r=−0.73; P=0.026). No other significant correlations were indicated for any of the other preference variables.

Factors relating to apple purchase decisions

PLS regression was applied to the eating quality clusters and cluster membership (Y variables) were projected onto the residuals of the importance ratings given to external attributes and the hedonic liking of conceptual sensory attributes (X variables) (Fig. 10). Sour taste, in particular, and also soft ripe texture contributed greatly to the formation of the plot, indicated by their positions at the opposite ends of the first component (Fig. 10). Prominent apple flavour, juiciness, crisp texture, sweet taste and peeling apple fruit before eating contributed to the variation on the second component. E1 had a close association with slight apple flavour, slight internal browning, soft ripe texture, spongy texture, mealiness and price, but dissociated from crisp texture, juiciness, prominent apple flavour, prominent apple aroma and colour. E2 associated with sweet taste, size and shape of fruit, but separated from sour taste, bitter taste, astringency and cultivar loyalty. E3 associated with sour taste, bitter taste, and also with cultivar loyalty, familiarity with cultivar and cultivar indication on the packaging, but dissociated from sweet taste (Fig. 10).

PLS regression was also applied to the appearance clusters and cluster membership (Y variables) were projected onto the residuals of the importance ratings given to external attributes and the hedonic liking of conceptual appearance attributes (X variables) (Fig. 11). Full green colour contributed significantly to the formation of the plot, indicated by its position on the left side of the first component. Full red colour and cultivar name indication on packaging (name indicated) contributed to variation on the second component. A1 associated with full yellow, striped red and bi-colour red peel colouring patterns and dissociated from full green colour. A2 associated with bi-colour pink peel colour, as well as external attributes such as size, shape, colour and price. A2 dissociated from blush pink, blush red, as well as from loyalty to specific cultivars, familiarity with cultivar and cultivar name indication on the packaging. A3 associated with full green, blush red colour, cultivar name indication on the packaging, familiarity with cultivar and cultivar loyalty, but

dissociated from full yellow, striped red, bi-colour red and also from peeling an apple before eating it.

Discussion

The overall actual and conceptual preference patterns for apple eating quality and appearance among consumers from different ethnic (black, white and Indian) and age (18-25 and 26+) groups in the Gauteng and Kwa-Zulu Natal provinces were identified in Papers 1 and 2, respectively. Black and older consumers generally had a higher preference for sweet taste and a lower preference for sour taste compared to young white Gauteng and young Indian Kwa-Zulu Natal consumers whose preference for apple eating quality was driven by textural attributes such as crispness, crunchiness, hardness and juiciness. However, the mean preference scores that were obtained can only show general tendencies, but not segregation of consumer into distinct clusters (Carbonell *et al*., 2008).

Preference for eating quality

In agreement with studies conducted among British (Daillant-Spinnler *et al*., 1996), Spanish (Carbonell *et al*., 2008), French (Symoneaux *et al*., 2012), Western Cape (Van der Merwe, 2013) and European (Bonany *et al*., 2014) consumers, the current study revealed a clear consumer segment that preferred sour taste (E3) and a consumer group that disliked it (E2). Consumers in E1 liked sweet taste and also had a tolerance for sourness. Unlike the current study, Vigneau and Qannari (2002) identified only two groups of French consumers with differing preference pattern for apple eating quality. In concurrence with our study, the first group in the study by Vigneau and Qannari (2002) associated with firmness factors such as juiciness and crisp texture, as well as acid/green flavour (sourness) and a dislike for spongy texture, while the second group preferred sweetness. Carbonell *et al*. (2008), as in our study, applied Ward's clustering analysis to preference data, but obtained four different consumer groups with 29% of the total consumers liking crispy, hard apples with sour taste and disliking mealy apples, and 22% liking sweet taste, tolerating mealiness, but disliking sour taste. The other two consumer groups that constituted 49% of the total consumers had a predilection for apple flavour and textural attributes with medium intensities. Van der Merwe (2013) also identified three eating quality clusters among Western Cape consumers employing Ward's clustering method, but contrary to the current study where two consumer

groups (E1 and E2) had similar preferences, all three clusters showed distinct preferences. Van der Merwe's cluster 1 showed a preference for firmness, tolerated sour taste and disliked sweet taste and mealiness; cluster 2 liked sour taste and apple flavour, while cluster 3 disliked sour taste. E1 and E2 in our study differed in their preference for sponginess. E1 associated with sponginess while E2 did not. Using the clustering of incomplete preferences (CLIP) technique, Bonany *et al*. (2014) identified six different clusters grouping into two main mega clusters among consumers of seven European countries. In accordance with our study, mega cluster A (68% of consumers) associated with sweetness, while mega cluster B (32% of consumers) preferred acidic-firm apples. Daillant-Spinnler *et al*. (1996) and Symoneaux *et al*. (2012) identified two consumer segments that constituted approximately equal proportions of the total consumer group using visual clustering of consumer preference data. In addition, in the study by Daillant-Spinnler *et al*. (1996), the consumer groups associated with either sweet, hard apples ('Fuji') or juicy, sour apples ('Granny Smith'). Also, contrary to the current study, Symoneaux *et al*. (2012) showed that French consumers preferred crunchy and sweet apples, but had a strong aversion for mealiness.

The preference of consumer segments that associated with sour taste was driven by 'Braeburn' and 'Granny Smith' (Daillant-Spinnler *et al*., 1996; Carbonell *et al*., 2008), while Van der Merwe (2013) showed that 'Granny Smith', 'Pink Lady®' and 'Sundowner®' (the trademark name Sundowner was since changed to Joya) were the preference drivers of consumers that preferred sour taste. The consumer group that preferred sour taste in the study by Van der Merwe (2013) had preference for 'Pink Lady®' because apple flavour was also a preference driver. 'Braeburn' and 'Granny Smith' also associated with preference for sour taste in our study. The preference of consumer segments that liked sweet taste, but disliked sour taste was driven by 'Topred' and 'Golden Delicious' (Daillant-Spinnler *et al*., 1996; Carbonell *et al*., 2008; Van der Merwe, 2013), as well as 'Fuji' and 'Golden Delicious' (Bonany *et al*., 2014). The current study revealed that the preference of the two consumer segments that liked sweet taste but disliked sour taste was driven by 'Fuji' and 'Topred'. It is, however, worthwhile to note that consumers in E1, although indicating a significantly higher preference for 'Topred' and 'Fuji', showed a high liking for almost all nine cultivars used in the present study. This might suggest that consumers in E1 like apples in general and thereby could be a target market for almost all the apple cultivars supplied on the domestic market.

Our suggestion is supported by the fact that consumers in E1 indicated that they buy and consume apples more frequently compared to E2 and E3.

Variations in sensory attributes in relation to the cultivars used for this study may have posed a challenge to singling out specific taste and texture attributes that influenced the preferences of the identified clusters. Therefore, the association of sweet tasting cultivars used in this study with mealiness could have resulted from a simultaneous increase in apple sugar levels and the development of mealiness during ripening and storage (Visser *et al*., 1968; Carbonell *et al*., 2008). In addition, although mealiness is considered a negative attribute (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Symoneaux *et al*., 2012), consumers in E1 and E2 may tolerate mealiness and sponginess due to a high preference for sweet taste. Likewise, the E3 consumer group may tolerate sour taste because of their predilection for sensory attributes associated with firmness. The association of firmer cultivars used in this study with sourness and the presence of these attributes on the same axis of the preference map could have a biological or genetic basis (King *et al*., 2000; Harker *et al*., 2003).

The general preference patterns of E1, E2 and E3's consumers were also evident in the factors that influence their apple purchase decisions. E1 and E2 consumers' indicated that sweet taste influences their decision to buy one apple cultivar or the other while the purchase decisions that impact E3 consumers are sour taste and crisp texture.

Socio-demographic factors for eating quality clusters

Although each consumer segment was characterised by a higher representation of consumers with specific socio-demographic backgrounds, consumers from all ethnic and age groups, as well as all socio-economic backgrounds included in our study were present in all three clusters. The E1 and E2 clusters that preferred sweet taste, tolerated mealiness and sponginess (E1), but disliked sour taste was made up of higher proportions of black and older consumers. E1 (38% of the total consumer group) constituted 45% of the black Kwa-Zulu Natal and 45% of the older (26+) consumers, while E2 (37%) constituted 43% of the black Gauteng and 40% of the older consumers. This is in accordance with results obtained in Paper 1, which indicated that the attributes that generally drive the preference of black and older consumers for apple eating quality are sweet taste, tolerance of mealiness and an

aversion for sour taste. The results also concur with findings by Van der Merwe (2013) for Western Cape consumers. Van der Merwe's consumer group that liked sweet taste but had an aversion for sour taste contained 48% of the total consumer group with an over-representation of black consumers (54%). E3 (25% of the total consumer group) had an over-representation of white Gauteng (38%) and Indian Kwa-Zulu Natal (33%) consumers. The Gauteng province population consists of 74% black and 20% white consumers, while Kwa-Zulu Natal province has 85% black and 9% Indian consumers (STATSSA, 2013). When considering these consumer demographics in Gauteng and Kwa-Zulu Natal, we find that twice as many black consumers compared to white consumers in Gauteng and five times as many black consumers compared to Indian consumers in Kwa-Zulu Natal potentially fall within E3. Thus, a considerably higher number of black compared to white and Indian consumers in Gauteng and Kwa-Zulu Natal, respectively, are partial towards firm and sour apples. Hence, marketers and distributors could also target sour cultivars at sour-liking black consumers represented in E3 despite the general sweet taste preference of black consumers. Van der Merwe (2013) also found a good representation of black and coloured consumers in the Western Cape Province, who on average exhibited general liking tendencies for sweetness rather than sourness in the eating quality cluster that was predominantly white and preferring sour tasting cultivars.

E1's higher correlation with sweet taste and positive association with sponginess compared to E2 probably explains why more male consumers are represented in E1 compared to female consumers. Male consumers' higher representation in E1 concurs with findings in Paper 1 of our study where male consumers showed a greater liking for sweet taste compared to female consumers. E2 consumers disliked sour taste. The overrepresentation of females in this group is consistent with the lower preference of female consumers for sour tasting 'Granny Smith'. Female consumers in E2 may under normal circumstances not be willing to purchase 'Granny Smith', but since they are predominantly responsible for purchasing apples for the entire household (Paper 2), marketers and distributors could still target firm, moderately sour to sour cultivars such as Honeycrisp, Joya™, Pink Lady®, Braeburn and Granny Smith at both male and female consumers represented in E2. E3, however, had an equal representation of male and female consumers.

E1 had a higher proportion of the lower Living Standard Measures (LSM) group of consumers who did not obtain final school year qualification compared to E2 and E3. In addition, consumers who did other jobs (neither student, technical nor administrative staff nor being professional) had the highest representation in E1. However, E1 constitutes the largest proportion of regular apple buyers. The association of E1 with frequent fruit and apple buying as well as with frequent apple consumption may have been influenced by the higher proportion of older consumers in E1. The predominance of students and young (18-25) age group consumers in E3 probably explains why consumers in E3 bought and consumed apples less frequently. Apples are a commodity fruit in South Africa and generally available at lower prices compared to speciality crops. Hence, it might be more affordable to poorer consumers. However, E1 consumers not only buy apples more frequently, but also generally buy fruit more regularly than consumers in the other eating quality clusters.

Preference for appearance

A1 formed the largest proportion (43%) of the total consumer group and contained a higher proportion of black, older and male consumers. Like the E1 consumer group, which showed preference for a variety of apple cultivars, the appearance preferences of the A1 consumer group was also for a diverse range of apple cultivars except for 'Granny Smith', which this group of predominantly older, male consumers disliked. A1 appearance preferences associated with traditional sweet cultivars such as Royal Gala (striped red), Golden Delicious (green/yellow) and Topred (full red), as well as newer cultivars such as Honeycrisp (striped red) and Pink Lady® (blush pink). Red cultivars (Steyn, 2012) and green/yellow Golden Delicious (Daillant-Spinnler *et al*., 1996; Carbonell *et al*., 2008; Van der Merwe, 2013) are associated with sweet taste. This association of A1 consumers would concur with the general eating quality and appearance preference tendencies as well as the conceptual indication of colour preferences of black, older and male consumers (Paper 1) that are overrepresented in this group. The preference of A1 consumers for the pink blush colour of 'Pink Lady®' cannot be readily explained. The 'Pink Lady®' apples used in our study associated with sweet taste and high flavour (Paper 1). However, it is not normally considered a sweet cultivar and consumers would not be able to link the appearance of cultivars used in the study to the samples that they tasted. The dislike of A1 consumers for green 'Granny Smith' may relate to the association of green cultivars with sourness (Daillant-Spinnler *et al*., 1996).

The A2 consumer group constituted 38% of the total consumer group and had a higher proportion of white, Indian, young (18-25) and female consumers. A2 consumers indicated a high preference for green 'Granny Smith' and red 'Topred' and a comparatively lower preference for 'Braeburn', 'Fuji' and 'Golden Delicious'. The A2 consumers seemed to dislike dull and mottled coloured fruit such as the 'Fuji' and 'Braeburn' fruit used in the present study. Considering that 'Fuji' and 'Topred' associated with sweet taste, while 'Braeburn' and 'Granny Smith' associated with sourness (Paper 1), the preference pattern of the A2 consumer group was not consistent with their eating quality preferences. It seems that A2 consumers gave high scores to apples that were attractive to them and were not familiar with the appearance of their preferred apples in terms of eating quality. The higher representation of young (18-25) consumers in the A2 consumer group may have accounted for size being amongst the important purchase factors (colour, shape and size) for these consumers, following the indication of size as the second most important factor that influences the purchase decision of consumers in the young age group (Paper 2).

A3 consumers constituted 19% of the total consumer group and contained a higher proportion young white Gauteng and young Indian Kwa-Zulu Natal consumers. The preference of A3 consumers was for green 'Granny Smith' while they had an aversion for red 'Topred'. Young white and young Indian consumers generally preferred firm, green 'Granny Smith' and these consumers have an aversion to cultivars associated with mealiness such as Royal Gala, Golden Delicious and Topred (Paper 1). A3 consumers also indicated that their apple purchase decisions associates positively with green peel colour.

Correspondence between eating quality and appearance cluster membership

Correlations between consumers' cluster membership based on their preference for eating quality and consumers' cluster membership based on their preference for appearance revealed that Topred, Fuji and Royal Gala were the most important cultivars associated with the preference of consumers in E1, E2 and A1, while Granny Smith was the most important cultivar associated positively with the preference of consumers in E3, A2 and A3. The preference of E1, E2 and A1 consumers associated with 'Topred', 'Fuji' and 'Royal Gala' because of their preference for sweet taste (Daillant-Spinnler *et al.*, 1996; Carbonell *et al.*,

2008; Steyn, 2012; Van der Merwe, 2013; Bonany *et al*., 2014). The association of E3, A2, and A3 with 'Granny Smith' is probably due to their preference for sour tasting apples.

Except for the E2 consumer group, the eating quality preferences of the consumer groups generally correlated with their respective appearance preferences. E2 correlated positively with A1 but had a negative correlation with A3. Both E2 and A1 indicated a dislike for the sour 'Granny Smith' while A3 consumers had a preference for 'Granny Smith'. However, the high liking of E2 consumers for the eating quality of 'Fuji' did not correlate with their dislike of its appearance. Although the eating quality of 'Fuji' used in our study associated with sweet taste (Daillant-Spinnler *et al*., 1996), but the fruit were dull and mottled red in colour and therefore not characteristic of the red cultivars that consumers usually associate with sweetness (Steyn, 2012).

It seems that consumers were generally aware of the association between an apple's colour and its eating quality attributes. For example, consumers with a preference for firmness and a dislike of mealiness indicated a higher preference for green colour and a 'Granny Smith' picture while they indicated a dislike for full red colour and the appearance of 'Topred'. The role of familiarity in apple purchase decisions was exemplified by a study of Van der Merwe *et al*. (2015) where consumers gave higher eating quality scores for 'Pink Lady™' when samples were presented with photograph of 'Pink Lady®' compared to when no photograph or photographs of 'Starking' and 'Golden Delicious' were presented. This finding was attributed to consumers' growing familiarity with 'Pink Lady®' and the positive image that the consumers who participated in the study had of the cultivar. On the contrary, but in accordance with our study, 'Fuji' was scored higher in terms of eating quality preference when consumers were not presented with its photograph. This indicates that consumers are unable to identify 'Fuji' apples although they like its eating quality. This is possibly because consumers are generally not familiar with 'Fuji' apples. Marketers will have to develop programmes to enable consumers to identify 'Fuji' apples and associate its eating quality with its appearance. The same applies to other new cultivars, especially those like yellow, crisp Opal (Brown and Maloney, 2013) where the appearance and eating quality attributes deviates from normal associations and consumer expectations.

Conclusions

Three consumer clusters were identified for each of eating quality and appearance preferences. Differences in cluster membership in general resulted from consumers' predilection for either sweet, red cultivars (i.e. Topred) or sour, firm and green cultivars (i.e. Granny Smith). The largest proportion (75%) of the total consumer group, and consisting predominantly of black and older consumers, liked sweet taste, tolerated mealiness and sponginess but disliked sour taste. Cluster segregation within this larger sweet-liking group was mainly due to the 38% of consumers who tolerated both sponginess and sourness and in fact showed a high liking for all the apple samples that they tasted. These consumers also indicated a more frequent consumption of apples. The remaining 25% of mainly young white and young Indian consumers preferred firm and sour cultivars but had an aversion to mealiness and sponginess.

Even though the current study confirmed the general perception that black and older consumers prefer sweet tasting apples, tolerate mealiness to a certain extent, but have a strong aversion for sour taste, the consumer group that was predominantly white, Indian and young and had a preference for firm and sour tasting cultivars, constitute twice and five times as many black consumers compared to white and Indian consumers respectively, in terms of the total populations in Gauteng and Kwa-Zulu Natal. Therefore, not targeting firm and sour cultivars at the group of black consumers who prefer firm and sour tasting apple cultivars would constitute a lost sales opportunity. The segregation of the sweet-liking consumers into two groups was seemingly based on varying levels of tolerance to texture and flavour attributes such as mealiness, sponginess and sourness. That being said, the level of tolerance of consumers to mealiness and sponginess could not be clearly ascertained because of the very low level of mealiness attained during storage in this study.

In terms of appearance preferences, one consumer segment seemed to like the appearance of all cultivars except Granny Smith, another segment liked Granny Smith the most and full red cultivars considerably less while a third segment had a relative high liking of all the appearances except for the dull and mottled appearance of the Fuji and Braeburn apples used in the study. Hence, except for 'Fuji', which was liked by black and older consumers in terms of eating quality, but was disliked in terms of its appearance, consumers' appearance

preferences generally correlated with their eating quality preferences. 'Sweet-liking' consumers seem to like all apple appearances except for green 'Granny Smith'. This group of consumers like apples of all tastes and appearances, except when the apples are unattractive. 'Sour-liking' consumers prefer the appearance of Granny Smith.

Conclusions from this study were largely based on the preferences of the predominant group(s) of each segment which gives an indication that consumers differed in their apple eating quality and appearance preference (in concurrence with findings of Paper 1 and also with the study by Van der Merwe, 2013). However, there was fair representation of all consumers in each segment. Marketers and distributors should target cultivars at all consumers represented in each cluster and not only at predominant consumers in order to maximise sales. Apple sales could possibly be increased if retailers could assign shelf space to different cultivars based on the liking of specific consumer groups that favours the particular outlets.

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Table 1 Socio-demographic information of each eating quality preference cluster, presented per region, ethnic group. Values indicate the percentage of consumers from each of the four region, ethnic groups for age group and breakdown for gender, education, employment status, fruit buy, apple buy and consumption respectively, per cluster. The overall percentage of the subdivision of each socio-demographic group is presented in the last column

Socio-demographic factors		Cluster 1 (38% of total group)	Cluster 2 (37% of total group)	Cluster 3 (25% of total group)	Average
Region, ethnic groups					
Gauteng Black		37	43	20	**28**
Gauteng White		29	33	38	**22**
Kwa-Zulu Natal Black		45	38	17	**34**
Kwa-Zulu Natal Indian		35	32	33	**16**
Age groups					
Total	Young (18-25)	34	36	30	**66**
	Older (26+)	45	40	15	**34**
Gauteng Black	Young (18-25)	35	42	23	**19**
	Older (26+)	42	45	13	**9**
Gauteng White	Young (18-25)	23	32	45	**14**
	Older (26+)	39	36	25	**8**
Kwa-Zulu Natal Black	Young (18-25)	41	40	19	**23**
	Older (26+)	54	35	11	**11**
Kwa-Zulu Natal Indian	Young (18-25)	31	22	47	**10**
	Older (26+)	40	49	11	**6**
Gender					
Total	Male	41	35	24	**39**
	Female	36	39	25	**61**
Education					
Total	Tertiary	36	39	25	**64**
	Matric (final school year)	38	35	27	**31**
	Not final school year	52	29	19	**5**
Employment status					
Total	Student	36	35	29	**68**
	Technical	31	46	23	**5**
	Administrative	43	43	14	**8**
	Professional	39	47	14	**10**
	Other	51	34	15	**9**
Fruit buy					
Total	Frequent (≤ 2-3x week)	40	39	21	**37**
	Less frequent (≤ 1x month)	36	37	27	**63**
Apple buy					
Total	Frequent (≤ 2-3x week)	49	34	17	**28**
	Less frequent (≤ 1x month)	33	39	28	**72**
Apple consumption					
Total	Frequent (≤ 2-3x week)	43	37	20	**57**
	Less frequent (≤ 1x month)	31	38	31	**43**

Table 2 Socio-demographic information of each appearance preference cluster, presented per region, ethnic group. Values indicate the percentage of consumers from each of the four region, ethnic groups for age group and breakdown for gender, education, employment status, fruit buy, apple buy and consumption respectively, per cluster. The overall percentage of the subdivision of each socio-demographic group is presented in the last column

Socio-demographic factors		Cluster 1 (43% of total group)	Cluster 2 (38% of total group)	Cluster 3 (19% of total group)	Average
Region, ethnic groups					
Gauteng Black		48	35	17	**28**
Gauteng White		26	55	19	**22**
Kwa-Zulu Natal Black		56	26	18	**34**
Kwa-Zulu Natal Indian		30	47	23	**16**
Age groups					
Total	Young (18-25)	36	40	24	**66**
	Older (26+)	57	34	9	**34**
Gauteng Black	Young (18-25)	44	38	18	**19**
	Older (26+)	57	30	13	**9**
Gauteng White	Young (18-25)	18	57	25	**14**
	Older (26+)	41	50	9	**8**
Kwa-Zulu Natal Black	Young (18-25)	49	29	22	**23**
	Older (26+)	71	20	9	**11**
Kwa-Zulu Natal Indian	Young (18-25)	17	47	36	**10**
	Older (26+)	51	46	3	**6**
Gender					
Total	Male	48	30	22	**39**
	Female	40	43	17	**61**
Education					
Total	Tertiary	43	38	19	**64**
	Matric (final school year)	38	43	19	**31**
	Not final school year	74	10	16	**5**
Employment status					
Total	Student	37	40	23	**68**
	Technical	54	19	27	**5**
	Administrative	51	43	6	**8**
	Professional	53	40	7	**10**
	Other	70	23	7	**9**
Fruit buy					
Total	Frequent (≤ 2-3x week)	46	39	15	**38**
	Less frequent (≤ 1x month)	42	37	21	**62**
Apple buy					
Total	Frequent (≤ 2-3x week)	53	34	13	**28**
	Less frequent (≤ 1x month)	40	40	20	**72**
Apple consumption					
Total	Frequent (≤ 2-3x week)	49	34	17	**57**
	Less frequent (≤ 1x month)	36	43	21	**43**

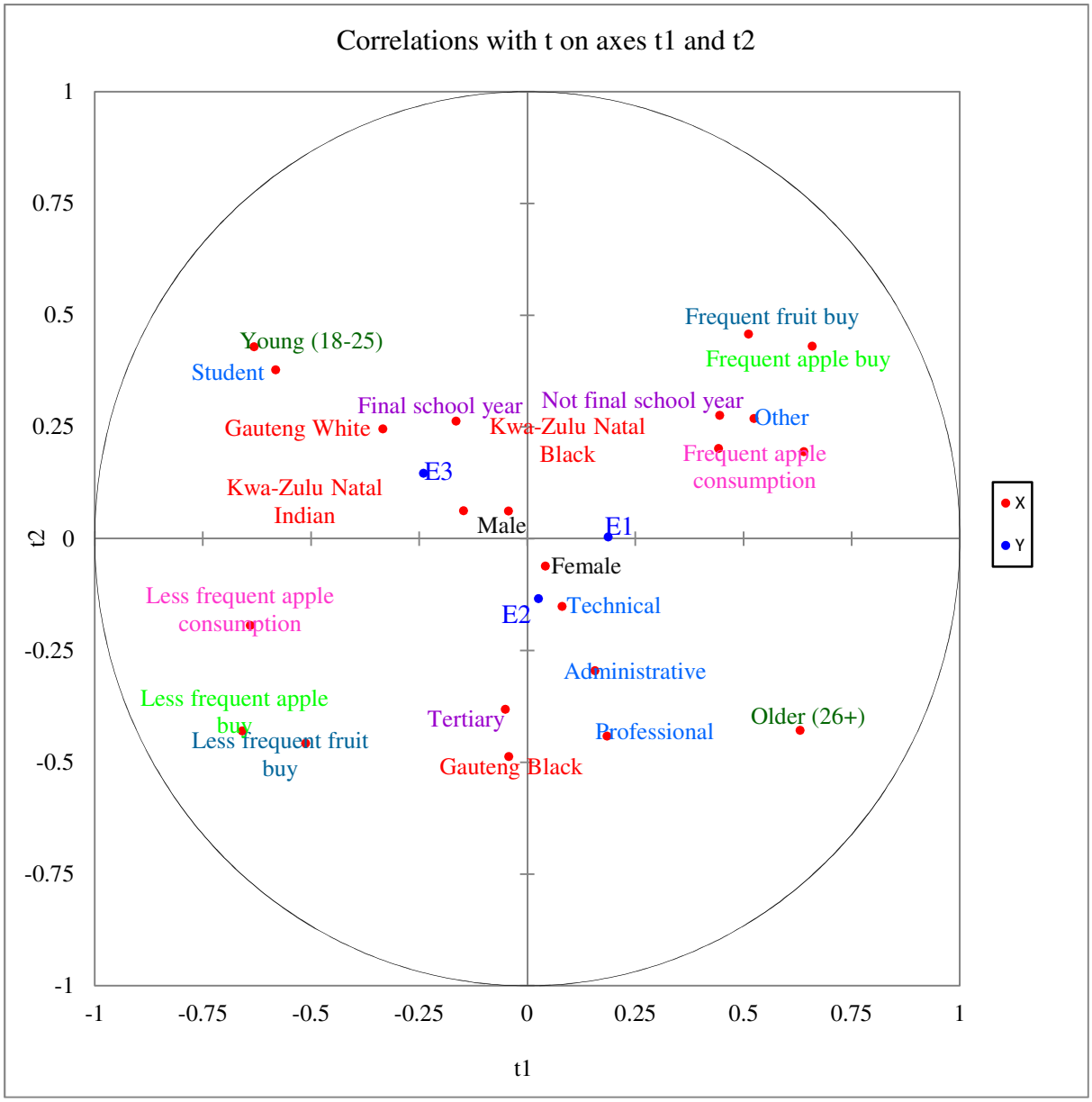

Figure 1 Partial least squares plot indicating the distribution of consumers' socio-demographic characteristics between the different eating quality clusters (E1-E3). Socio-demographic factors included region, ethnic group (Gauteng Black, Gauteng White, Kwa-Zulu Natal Black and Kwa-Zulu Natal Indian), age group (18-25 and 26+), gender (male and female), level of education (not final school year, final school year and tertiary), employment status (student, technical, administrative, professional and other), fruit buy, apple buy and apple consumption [frequent (≤ 2-3x week), less frequent (≤ 1x month)], respectively.

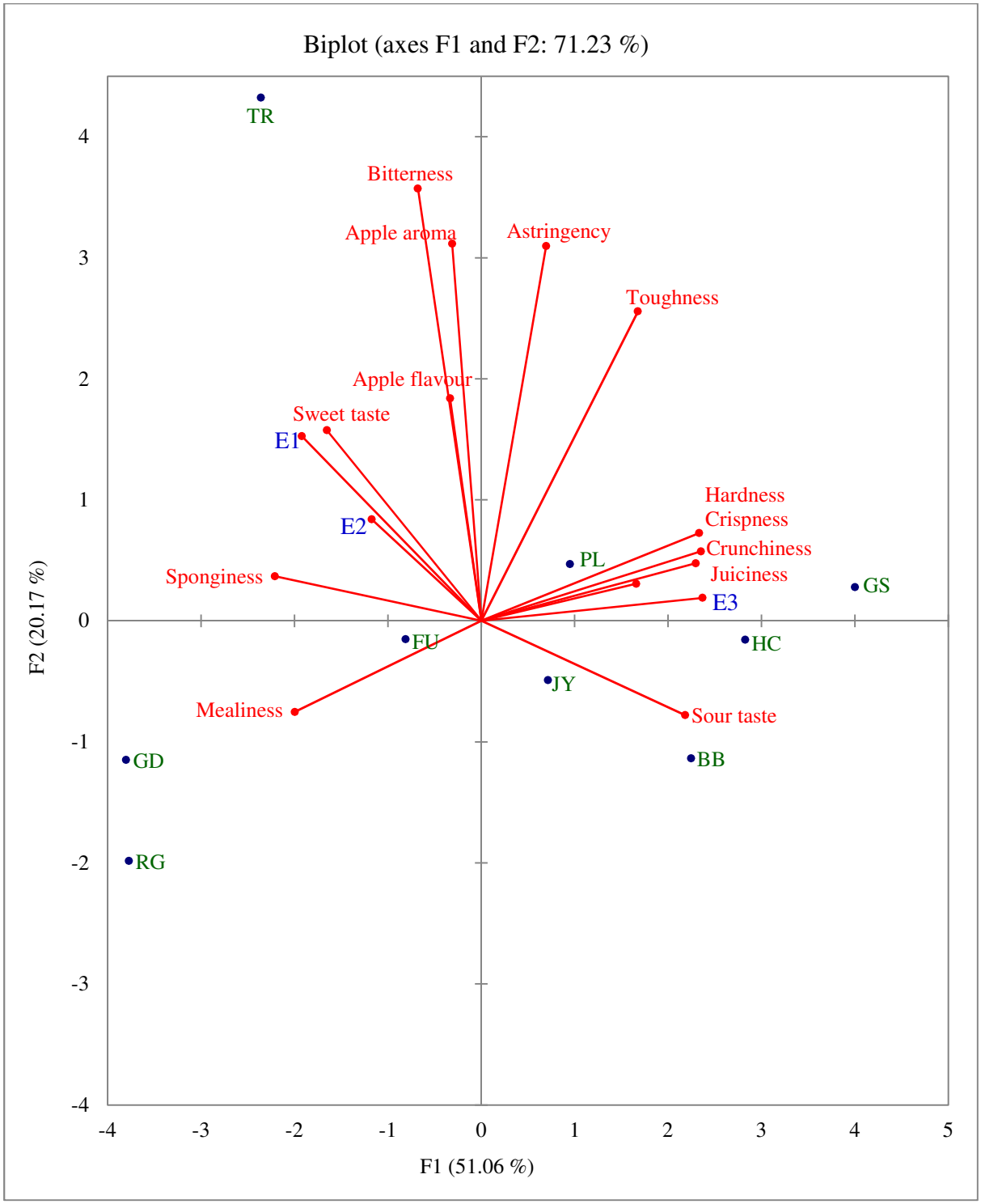

Figure 2 Principal component analysis bi-plot indicating the position of preference for the eating quality clusters (E1-E3) in relation to sensory attributes of apple fruit from nine cultivars, i.e., Braeburn (BB), Pink Lady®, (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ and Topred (TR).

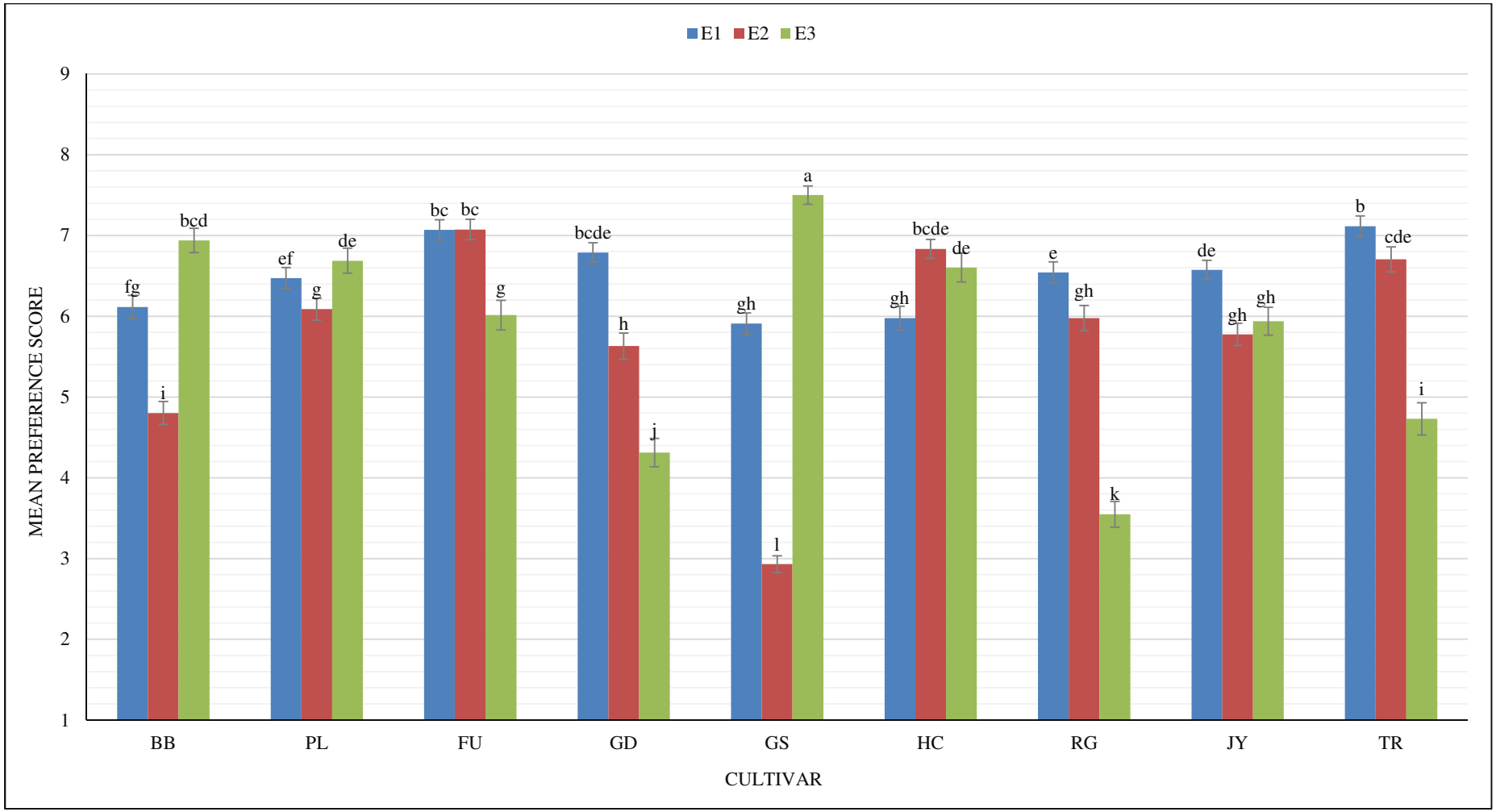

Figure 3 Mean preference scores for the eating quality of nine apple cultivars analysed by the eating quality clusters (E1-3), i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by the consumers from three different clusters. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5% level of significance.

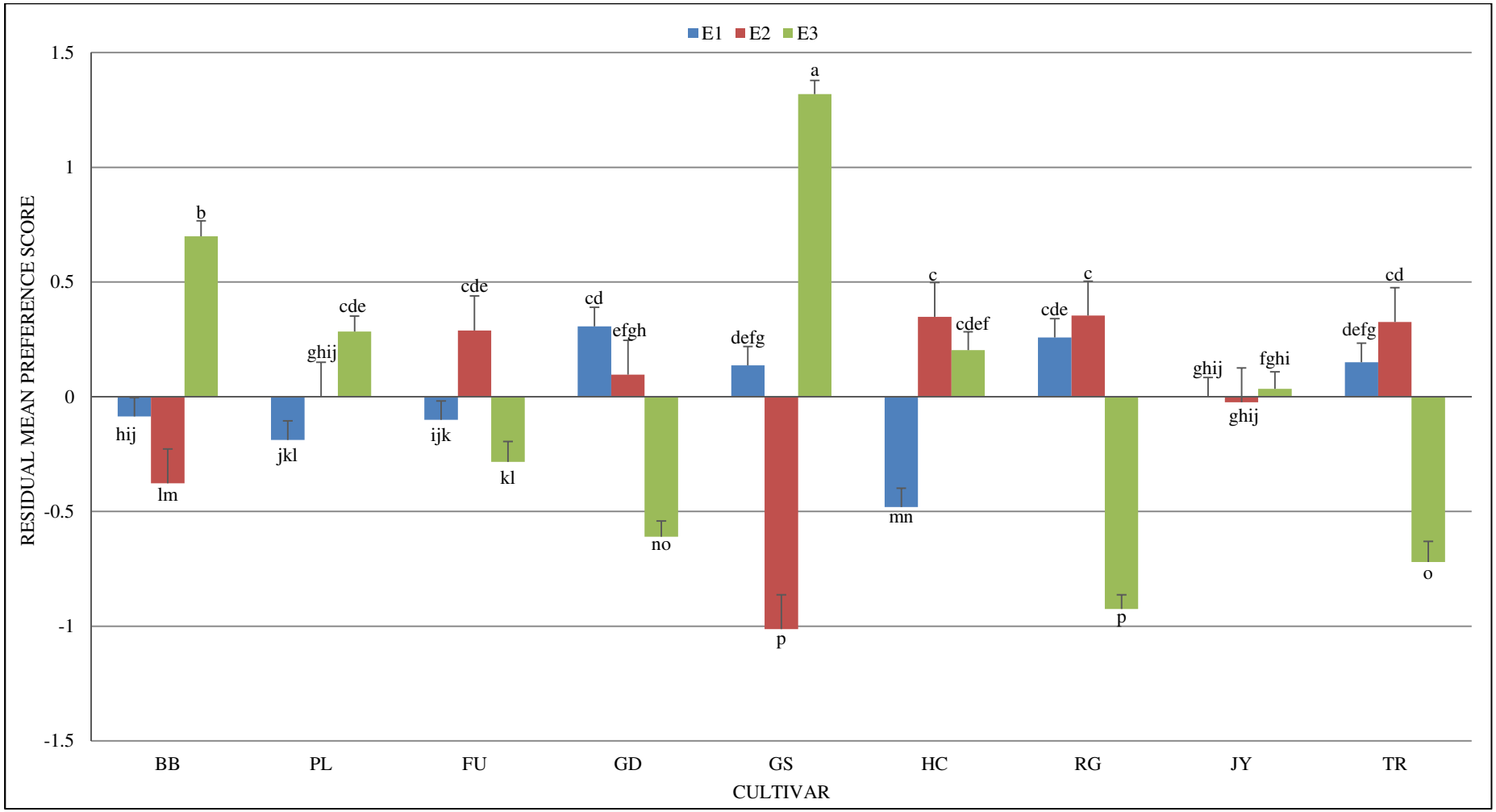

Figure 4 Residual mean preference scores for the eating quality of nine apple cultivars analysed by the eating quality clusters (E1-3), i.e., Braeburn (BB), Pink Lady®, (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by the consumers from three different clusters. Means + standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5% level of significance.

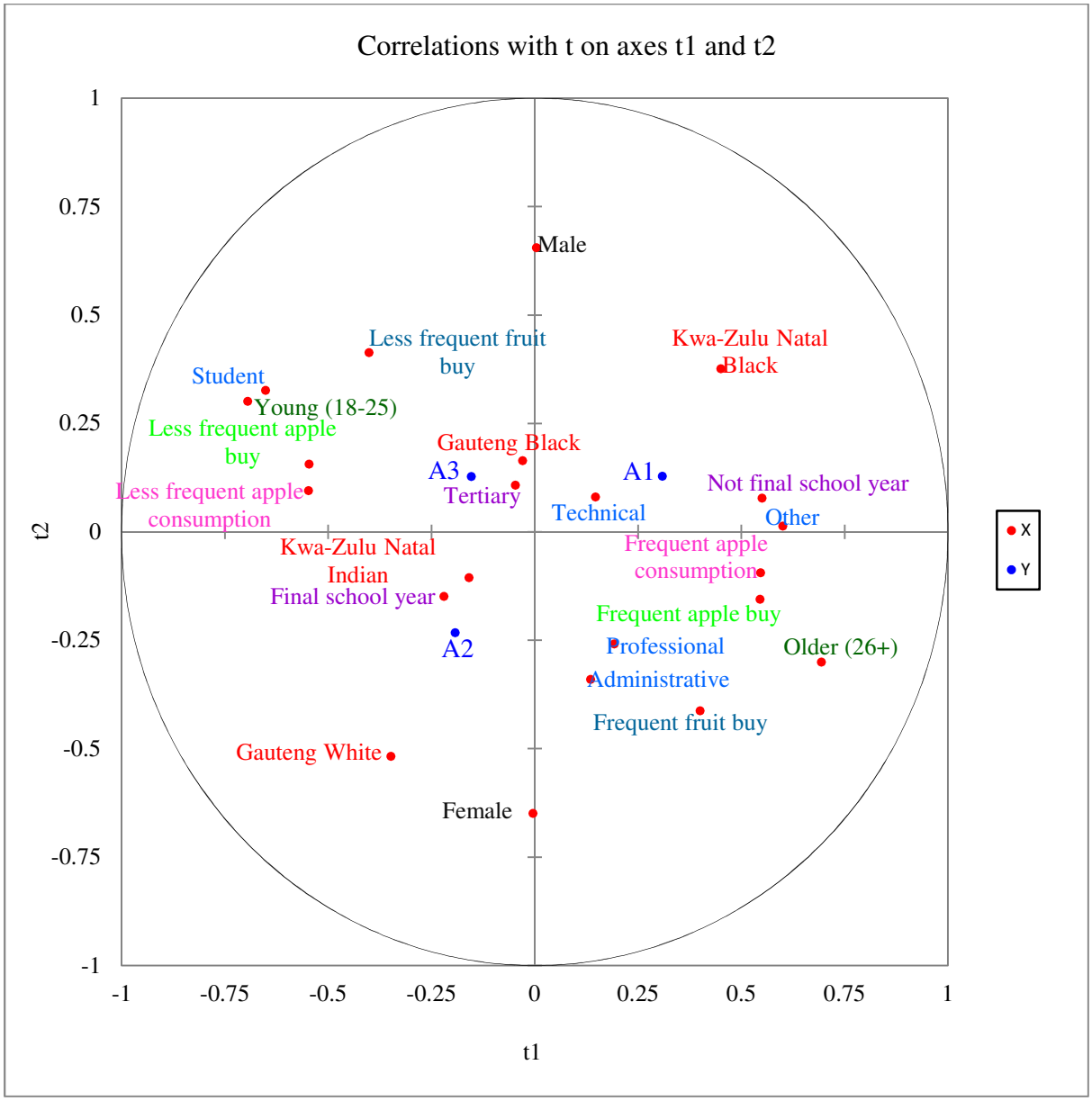

Figure 5 Partial least squares plot indicating the distribution of consumers' socio-demographic characteristics between the different appearance clusters (A1-A3). Socio-demographic factors included region, ethnic group (Gauteng Black, Gauteng White, Kwa-Zulu Natal Black and Kwa-Zulu Natal Indian), age group (18-25 and 26+), gender (male and female), level of education (not final school year, final school year and tertiary), employment status (student, technical, administrative, professional and other), fruit buy, apple buy and apple consumption [frequent (≤ 2-3x week), less frequent (≤ 1x month)], respectively.

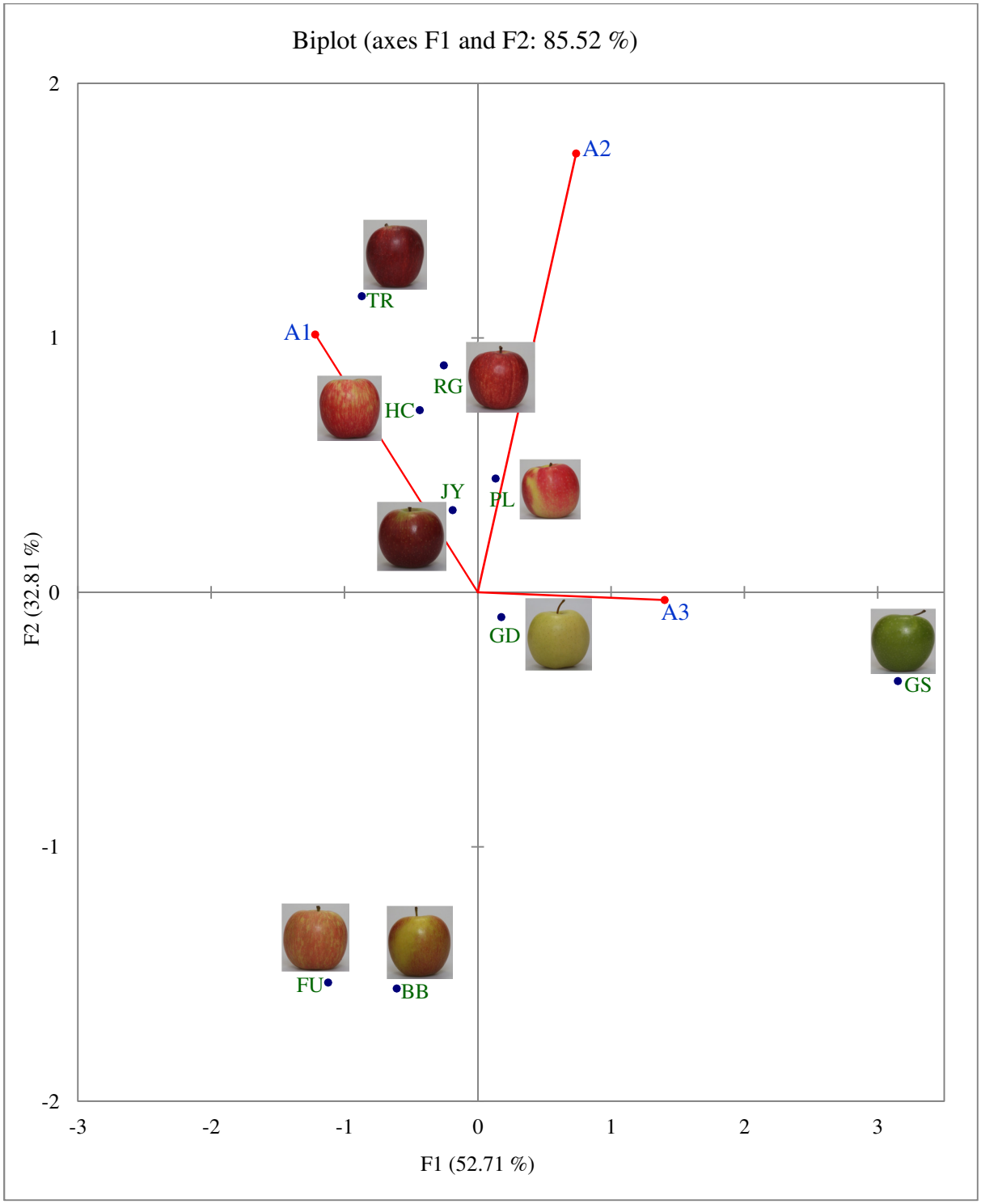

Figure 6 Principal component analysis bi-plot indicating the position of preference for the three appearance clusters (A1-A3) in relation to nine cultivars, i.e., Braeburn (BB), Pink Lady®, (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR).

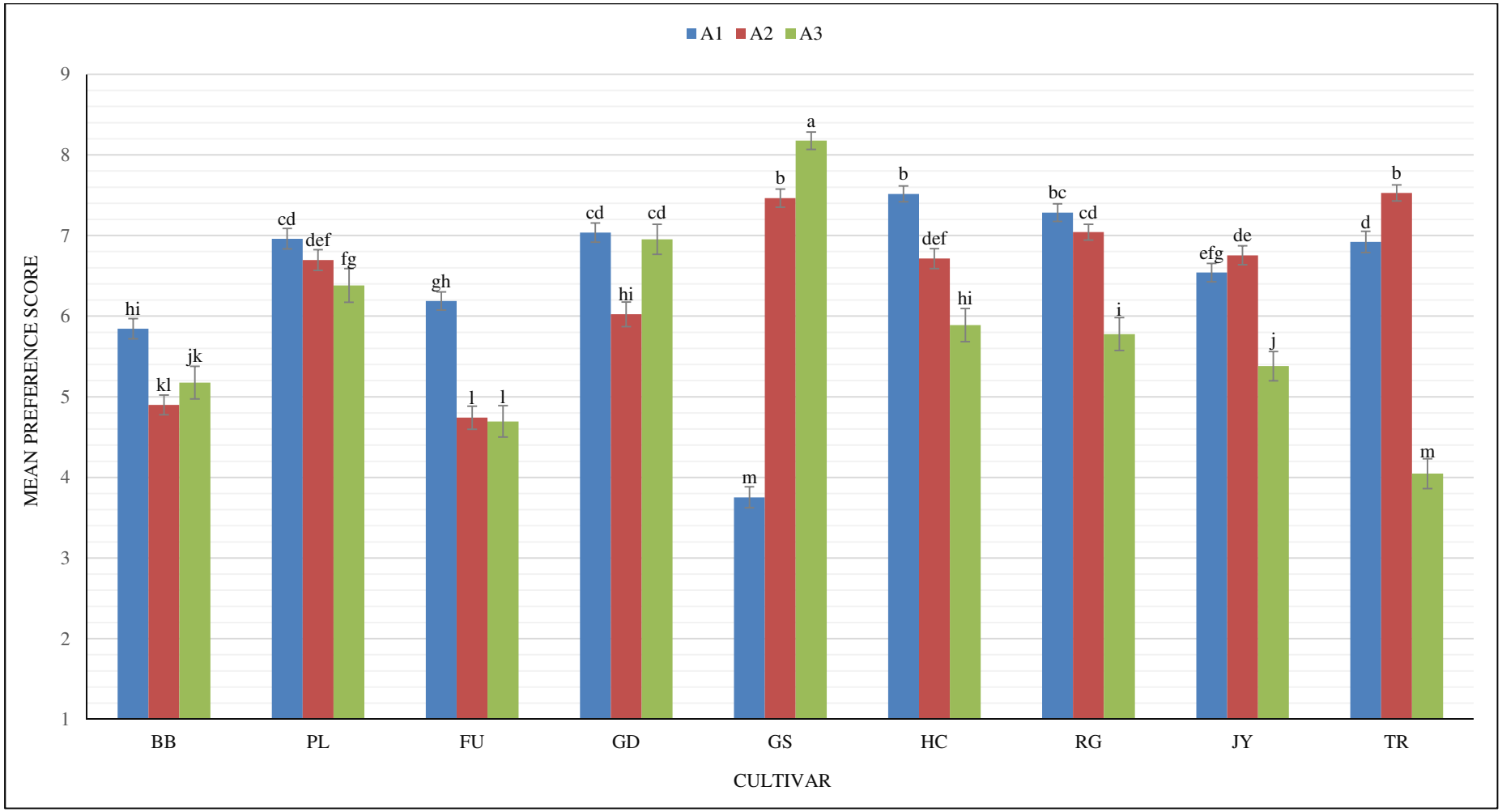

Figure 7 Mean preference scores for the appearance of nine apple cultivars analysed by the appearance clusters (A1-3), i.e., Braeburn (BB), Pink Lady® (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by the consumers from three different clusters. Means +standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5% level of significance.

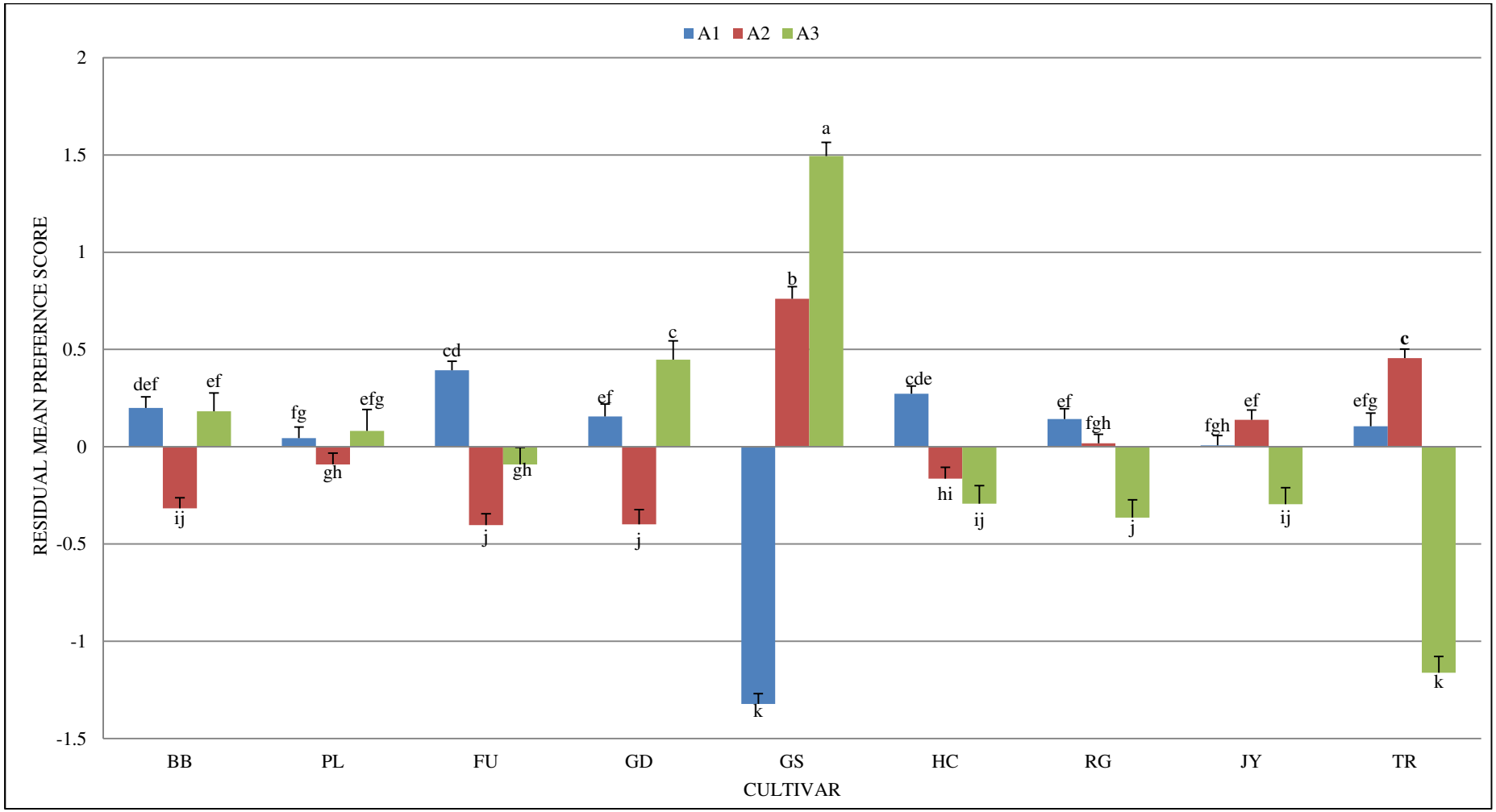

Figure 8 Residual mean preference scores for the appearance of nine apple cultivars analysed by the appearance clusters (A1-3), i.e., Braeburn (BB), Pink Lady®, (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR) by the consumers from three different clusters. Means +standard errors with different alphabetical letters differ significantly. The least significant difference within each group is indicated at the 5% level of significance.

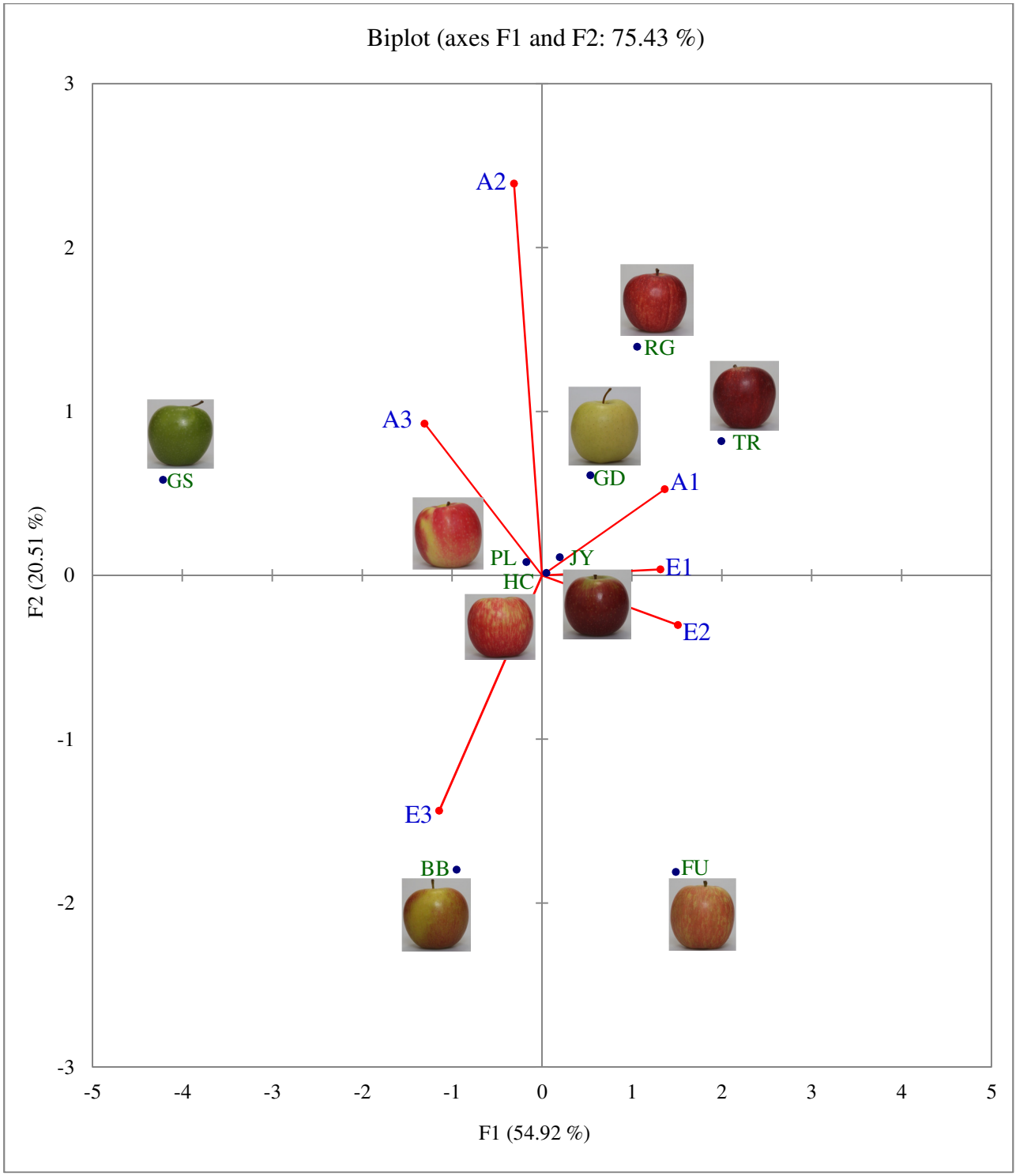

Figure 9 Principal component analysis bi-plot indicating the position of appearance preference (A1-A3) for the three clusters obtained by their responses to preference of eating quality (E1-E3) for the nine cultivars, i.e., Braeburn (BB), Pink Lady®, (PL), Fuji (FU), Golden Delicious (GD), Granny Smith (GS), Honeycrisp (HC), Royal Gala (RG), Joya™ (JY) and Topred (TR).

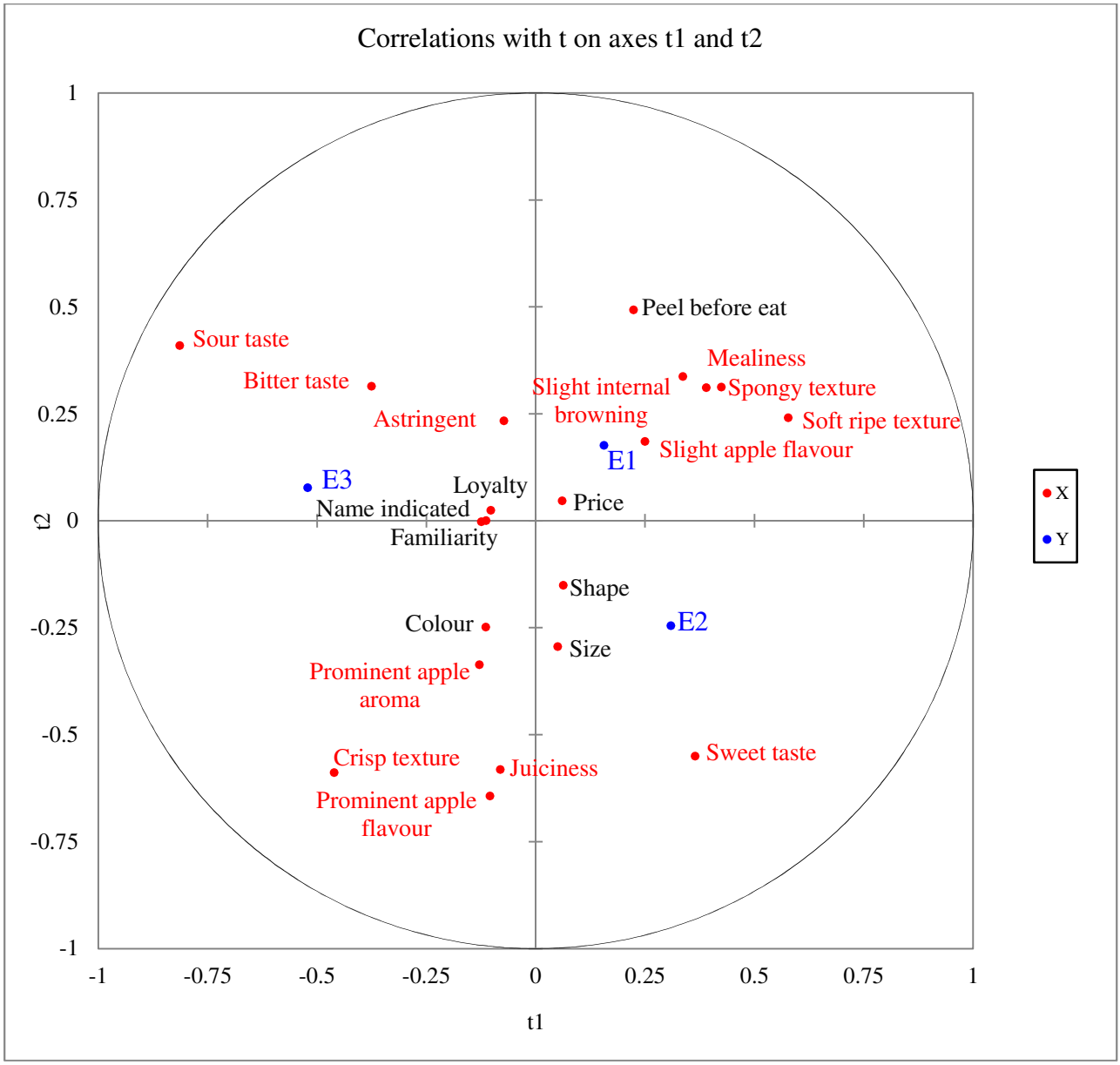

Figure 10 Partial least squares plot indicating the importance of purchase factors and the liking of conceptual sensory attributes of consumers from the three eating quality clusters (E1-E3). Purchase factors included colour of the apple (colour), loyalty to specific cultivars (cultivar loyalty), familiarity with cultivar (familiarity), cultivar name indication on the packaging (name indicated), price, size and shape of the apples.

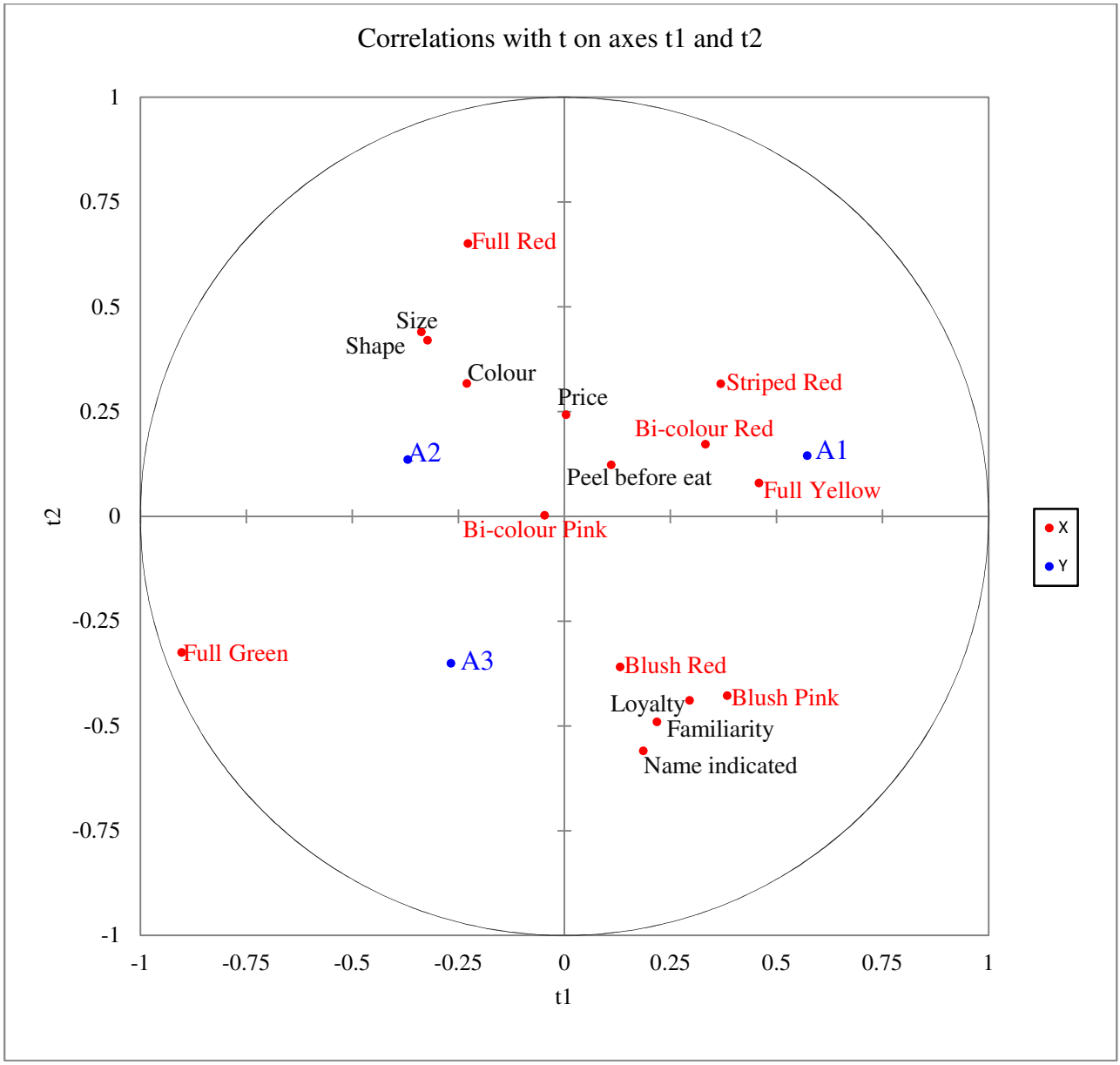

Figure 11 Partial least squares plot indicating the importance of purchase factors and the liking of conceptual appearance attribute of consumers from the three appearance clusters (A1-A3). Purchase factors included colour of the apple (colour), loyalty to specific cultivars (cultivar loyalty), familiarity with cultivar (familiarity), cultivar name indication on the packaging (name indicated), price, size and shape of the apples.

PAPER 4: PREFERENCE FOR APPLE FRUIT OF VARYING RIPENESS LEVELS AMONG SOUTH AFRICAN CONSUMERS OF DIFFERENT ETHNIC AND AGE GROUPS

Abstract

Consumer segments may differ in their acceptance of the appearance and eating quality characteristics of ripe apples, which may include such attributes as yellow ground colour, softness, mealiness, sweetness, sponginess and off-tastes and flavours. Previous research suggested that different ethnic and age groups may differ in their preference of these attributes, but these relationships were only studied indirectly. Therefore, this study set out to determine how black, coloured and white consumers of two age groups (18-25 or 26-61) in the Stellenbosch area of the Western Cape Province respond to apple fruit of varying ripeness levels. The commercial apple cultivars Golden Delicious (GD) and Topred (TR), harvested at optimum maturity, stored at -0.5 ºC for 15 and 16 weeks (for trained panel and consumer panel testing, respectively of 'GD' apples) and for 10 and 11 weeks (for trained panel and consumer panel testing, respectively of 'TR' apples), were subjected to five increasing shelf-life durations at 21 ºC of up to 21 (TR) and 28 days (GD) in 2013 and four increasing shelf-life durations of up to 27 days in 2014. This was done to attain variation in texture, taste and appearance attributes with increasing ripeness level. Descriptive sensory analysis was carried out on all shelf-life durations using a trained panel. Consumer preference of texture and taste quality, as well as appearance was assessed on a 9-point hedonic scale. Principal component analysis (PCA) was used to project the outcome of descriptive sensory analysis onto consumers' preference dimension. Consumer preference for the texture and taste quality of 'GD' declined slightly with increasing shelf life in both seasons when they tasted unpeeled fruit segments. Compared to other consumer groups, older black, older coloured, black male and coloured male consumers showed a greater liking for the texture quality of riper 'TR' apples in 2013, while coloured consumers of all ages and older male consumers showed a higher preference for the texture quality of riper, softer and more mealy 'TR' apples in 2014. Older and male consumers preferred the appearance of more yellow 'GD' apples and the appearance of riper 'TR' apples, whereas young and white consumers preferred the appearance of greener 'GD' apples. White consumers had a general dislike for the appearance of 'TR' apples compared to black and coloured consumers. The conceptual preference

indications of consumers generally associated with their actual quality liking scores. Apple appearance did not provide a good indication of eating quality characteristics. In the case of 'GD', eating quality changed much less than suggested by the yellowing of the peel while in 'TR', ground colour change was masked by the overlying red pigmentation. Our results indicate that coloured consumers, but older coloured consumers in particular could be a target market for riper apples with corresponding peel colour changes and apples could have a longer shelf-life duration in retail outlets predominantly serving coloured consumers.

Keywords *Malus x domestica* (Borkh.), ripeness level, consumer preference, principal component analysis, consumer groupings.

Introduction

Consumer preference for apple eating quality is driven by attributes such as sweet taste, moderate sour taste, apple flavour (characteristic of the particular cultivar), crispness, crunchiness and juiciness (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Andani *et al*., 2001; Van der Merwe, 2013; Bonany *et al*., 2014). Mealiness (a dry and floury texture) and very sour taste are eating quality attributes that negatively affect consumer preference for apple eating quality (Szezesniak and Kahn, 1971; Harker and Hallett, 1992; Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998).

Acceptable fruit texture and flavour quality tends to influence consumers' decision to choose a particular apple cultivar (McCracken *et al*., 1994; Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998). Although consumers generally prefer apples that remain crisp and juicy during their post-harvest life (Smith, 1985; Mitcham, 1997), they often have to deal with soft and/or mealy apples, whether or not that is their preference. This is because apples are prone to develop mealiness during ripening (Jaeger *et al*., 1998) and because various factors viz. stage of maturity (Harker *et al*., 1997, Richardson-Harman *et al*., 1998, Steyn, 2012), ripeness level (Richardson-Harman *et al*., 1998, Steyn, 2012), cold storage conditions and duration (Harker *et al*., 1997, Soliva-Fortuny *et al*., 2002; Varela *et al*., 2005), as well as the sell-buy date at point of sale (Harker *et al*., 1997) may all impact both the internal and external qualities of apple fruit.

Van der Merwe (2013), in evaluating the attributes that drive the preference of consumers in the Stellenbosch area of the Western Cape Province of South Africa, found that black and coloured consumers generally preferred sweet taste, which closely associated with mealiness. White consumers, on the other hand, generally had a strong aversion to mealiness. The predilection of black and coloured consumers for sweet taste was also evident in their appearance preference of full and striped red apples (Clydesdale, 1993; Steyn, 2012; Van der Merwe, 2013). Coloured consumers also had higher appearance preference for fruit with yellow compared to green ground colour. A more yellow ground colour in apples is associated with ripeness and such fruit are expected to be sweeter with high TSS:TA ratio, and if overripe, also soft or mealy (Lau, 1988; Kingston, 1992; Richardson-Harman *et al*., 1998; Van der Merwe, 2013). Our study, which focused on apple eating quality and appearance preferences of black and white consumers from Gauteng and black and Indian consumers from Kwa-Zulu Natal in South Africa, showed that young white and young Indian consumers generally preferred firm and sour apples, but disliked mealiness (Paper 1). This was also evident in their appearance preference for green 'Granny Smith' and their dislike of full yellow colour (Papers 1, 2). In contrast, black consumers generally preferred sweet taste, tolerated mealiness and disliked sourness when tasting fruit samples (Paper 1), but also when indicating their preferences conceptually (Paper 2). Black consumers also generally preferred green/yellow 'Golden Delicious' while older consumers disliked the appearance of green 'Granny Smith'. However, South Africa's 'Golden Delicious' fruit sold on the African continent would not be bought if peel colour is not green but yellow, since these consumers associate yellow peel colour with over ripeness (Henk Griessel, personal communication, July 23, 2015).

These findings notwithstanding, the extent to which any of these consumer groups associate with softness and/or mealiness has not been established. Also, no information is available on the tolerance of different consumer segments to apple fruit at progressive maturity levels, characterised by increasing softness, mealiness and progressive yellowing, as well as how different consumer segments relate ripeness level and texture with fruit appearance. This study, therefore, focused on how consumers of different ethnic and age groups in the Stellenbosch region of the Western Cape province of South Africa responded to apple fruit with varying maturity or ripeness levels. Although earlier studies considered mealiness a negative attribute (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Symoneaux *et al*.,

2012), British and Danish consumers did not exhibit any cross-cultural differences in relation to their preference for three apple cultivars with different mealiness levels (Jaeger *et al*., 1998). Also, even though British, Flemish, French, Spanish and Danish consumers used different terminologies in describing their perception of mealiness, Andani *et al*. (2001) found no cross-cultural difference in consumers' perception of mealiness. However, some Spanish (Carbonell *et al*., 2008) and Finnish (Seppä *et al*., 2013) consumers were found to have a liking for sweet, soft/mealy apples. In addition, although European consumers generally dislike mealiness (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998), Carbonell *et al*. (2008) indicated that a comparatively large fraction of Spanish consumers like mealy apples.

Appearance, particularly peel colour, is considered one of the most important factors that influence consumer preference for apple quality and fruit sales (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al*., 2002). Consumers' perception of fruit quality, especially in relation to fruit taste, as well as their decision to buy an apple, is largely influenced by fruit colour (Jaeger and MacFie, 2001; Shankar *et al*., 2010; Steyn, 2012). This is because most consumers usually evaluate fruit quality primarily via visual cues that provide information on acceptability (Steyn, 2012). External colour can provide an indication of freshness, ripeness, eating quality and cultivar (Richardson-Harman *et al*., 1998, Steyn, 2012). As apple fruit attain maturity and ripen, ground peel colour changes from green through to yellow and the peel may shrivel and become greasy (Lau 1988, Kingston, 1992, Varela *et al*., 2005). According to consumer surveys, apples with green ground colour are associated with firm and firm-related comments while more yellow ground colour induces more soft and soft-related comments (Richardson-Harman *et al*., 1998). Although different groups or segments of consumers are expected to differ in what they consider as acceptable in relation to fruit appearance (Gamble *et al*., 2006), there is limited information on consumers' apple appearance preferences in relation to different maturity or ripeness levels. There is therefore the need to study different levels or ripening of apple fruit and how it impacts on the preference of different consumer groups because varying ripening levels are associated with differences in the taste and textures as well as fruit appearance.

In view of the above, the aims of this research were to: 1) Determine if ethnic and age group significantly affect consumers' preferences for eating quality and appearance of apple fruit

with varying maturity or ripeness levels, and 2) ascertain the association of ripeness level and texture with fruit appearance.

Materials and methods

Plant material

Two apple (*Malus* x *domestica* Borkh.) cultivars, Golden Delicious (GD) and Topred (TR) were used for both the 2013 and 2014 studies. Five and four increasing shelf-life durations were used in 2013 and 2014, respectively. In both seasons, GD and TR apples of first grade export quality, were obtained from Kromco (Pty) Ltd, Grabouw. For all trials, apples were kept in regular atmosphere cold storage at -0.5 ºC and shelf-life at 21 ºC. In 2013, 'GD' apples were removed from cold storage after 15 and 16 weeks (for trained panel and consumer panel testing, respectively), and subjected to a shelf life period of 0, 7, 14, 21 or 28 days prior to assessments. 'TR' apples were sequentially removed from cold storage after 10 and 11 weeks (for trained panel and consumer panel testing respectively), and subjected to a shelf-life period at 21 °C of 0, 3, 7, 14 days and 21 days prior to assessment. In 2014, the 'GD' and 'TR' apples were sequentially removed from cold storage after 14 and 15 weeks and after 9 and 11 weeks, respectively. The shelf-life periods for both cultivars were 0, 9, 18, or 27 days. These increasing shelf-life durations were chosen to attain progressive levels of ripeness and associated differences in textural and flavour attributes, as well as peel colour.

Instrumental measurements

In 2013, each shelf-life duration treatment was replicated five times with three fruit per replicate, while in 2014, it was replicated eight times. In both years, the three fruit per replicate were analysed together as a replication set. Apples were removed from cold storage and kept at room temperature for the respective number of days corresponding with each treatment requirement before instrumental analyses commenced.

Flesh firmness (N) was measured using a penetrometer (Fruit Texture Analyser, GUSS Manufacturing (Pyt) Ltd., Strand, South Africa) fitted with an 11 mm diameter probe. Two readings were taken on opposite, peeled sides of the fruit approximately halfway between the calyx and the stem-end. Slices of apple were placed in a juice extractor and the juice was used to determine the total soluble solids (TSS) concentration and the titratable acidity (TA). TSS was measured using a calibrated hand-held refractometer (TSS 0-32%, Model N1,

Atago, Tokyo, Japan). TA was measured using an automated titrator (Tritino 719S and Sample Changer 674, Metrohm Ltd., Herisau, Switzerland) by titrating 10 g of juice from each apple sample with 0.1 M NaOH to a pH of 8.2. The TA was expressed as percentage malic acid. Percentage dry matter concentration (DMC) was determined by weighing a fresh sample of fruit and oven drying the fruit over a period of 48 h at 75 ºC. Samples were weighed immediately and returned to the oven for a further 48 h and re-weighed after every 24 h to ensure all the moisture had evaporated. DMC was determined as dry weight as a percentage of fresh weight.

The lightness and chroma values, as well as the hue angle were measured on the blushed side of each 'TR' apple using a colorimeter (Konica CR-400, Minolta Co. Ltd., Tokyo, Japan). The ground colour (measure of yellowness underlying the green colour and excluding any blush) of each 'GD' apple was scored by chart (Golden Delicious chart set A28, Unifruco Research Services Ltd, Bellville, South Africa).

Descriptive sensory analysis

Descriptive sensory analysis (DSA) of the samples was carried out using a panel consisting of eight female judges with prior experience in apple tasting. The judges were trained using the consensus method and analyses were performed according to the 'Generic Descriptive Analysis' (Lawless and Heymann, 2010). For the 2013 study, four training sessions were carried out on 26 and 29 July 2013 with two sessions per day using all ten samples. A total of eight training sessions were carried out during the 2014 study. Four training sessions were carried out on 21 and 23 July 2014 with two sessions per day using all four 'TR' samples. Another four training sessions were carried out on 29 and 30 July 2014 with two sessions per day using all four 'GD' samples. Judges were tested for consistency using PanelCheck (Nofima, Norway). Unstructured 100-point line scales were used for attribute intensity analysis. The left hand side of the scale corresponded to the lowest intensity and the right hand side corresponded to the highest intensity. The judges came to a consensus on a list of attributes for describing the flavour and texture of peeled samples for the attributes sweet taste, sour taste, apple flavour, overripe fermented flavour, crispness, hardness, crunchiness, juiciness and mealiness, as well as astringency, bitterness, and toughness of peel of unpeeled samples (Table 1).

In 2013, evaluation of samples was carried out on 30 and 31 July ('GD') and on 2 and 5 August ('TR'). In 2014, evaluation of samples was carried out on 24, 25 and 28 July ('TR') and on 31 July, 1 and 4 August ('GD'). One fruit, cut lengthwise, was equally shared between the judges such that each panel member received an eighth of an apple; thus all eight judges received the same apple. Each treatment was replicated six times with three replicates per day (2013) or replicated nine times with three replicates per day (2014). Each sample was coded with a three-digit random code and slices of unpeeled fruit were presented in petri dishes (Kimix, South Africa). Presentation of samples was done in a complete randomised design, balanced to minimise order and carry over effects (MacFie *et al*., 1989). The latter design was based on the Williams Design presented by Compusense® Five data collection software that collected data electronically (Version 4.2, Compusense Inc., Guelph, Ontario, Canada). Judges were seated in individual tasting booths with computers and standardised artificial daylight lighting and at a room temperature of 21 °C. Distilled water and unsalted fat free biscuits (Woolworths, South Africa) were provided as palate cleansers between samples.

Consumer analysis

Consumer recruitment

Consumer preference assessments were carried out in the Langenhoven Student Centre, Stellenbosch University, on 12 and 13 August 2013 for the 2013 assessments. The 2014 assessments were conducted on 5 August 2014 in the Sensory Laboratory of the Department of Food Science, University of Stellenbosch and on 6 August 2014 in the Langenhoven Student Centre, Stellenbosch University. A panel consisting of 450 (in 2013) and 240 (in 2014) black, coloured and white consumers, were recruited in the Stellenbosch area of the Western Cape Province for consumer panel testing. Consumers were grouped in young (18-25 years) and older (26+ years) age groups. The older age group (26+) ranged from 26 to 61, but a majority of these consumers were 26 to 40years old.

Consumers were asked to complete a structured questionnaire that consisted of four sections (Q1-Q4). Demographic and consumption information, i.e., gender, age and ethnic group, as well as apple consumption frequency, was collected in section 1 (Q1) (Appendix 9). Assessment of preference for actual eating quality and appearance were done in sections 2

and 3 (Q2 and Q3) (Appendix 10 - 15), respectively. General information on consumers' conceptual preferences for apple taste and texture attributes were collected in section 4 (Q4) (Appendix 16). In 2014, we also assessed the most preferred texture during consumption.

Preference for texture and taste quality

Unpeeled samples of all five (2013) and four (2014) shelf-life duration treatments for both 'GD' and 'TR', coded with a three-digit random code, were presented to consumers in open petri dishes on white trays in a completely randomised design, and balanced for order and carry-over effects. A sample consisted of an eighth of an apple, sliced from stem-end to calyx-end. Thus, every eight consumers received a sample set of the exact same fruit, while the next set of eight consumers received different fruit from the same treatments. In the actual eating quality assessment, consumers were asked to taste the fruit and to indicate, using a 9-point hedonic scale, which term best described how they perceived each apple sample they tasted in terms of their preference for the overall texture and taste, respectively. The 9-point hedonic scale ranges from 1 – *dislike extremely*; 5 – *neither like nor dislike* and 9 – *like extremely* (Lawless and Heymann, 2010). Distilled water was available for consumers to clean their palate between samples. A room temperature of 21 °C was maintained throughout the tasting.

Preference for appearance

Consumers were presented with life-sized, representative photographs of all five (2013) and four (2014) storage duration treatments for both 'GD' and 'TR' (Fig. 1-4), analysed in the eating quality test. Photographs were taken on 26 July 2013 and 23 July 2014 for the 2013 and 2014 consumer testing, respectively. Q3, comprising four pages of the structured questionnaire, contained the respective photographs with one cultivar per page. Each photograph page had a corresponding 9-point hedonic scale page. Photographs were assigned three-digit random codes.

Conceptual preference and purchase factors

Consumers' preference for certain apple sensory attributes considered when buying or eating an apple were assessed in section 4 (Q4) of the structured questionnaire. Consumers indicated their degree of liking for apple sensory attributes, viz. crispness, crunchiness, softness,

mealiness, sponginess, juiciness, sweet taste, sour taste, apple flavour, bitterness and astringency, on the 9-point hedonic scale.

Statistical procedures

The purpose of the study was to analyse the interaction between consumers' ethnic and age group, as well as their gender with their preference for the eating quality and appearance of apples of progressive ripeness and thus varying degrees of softness and/or mealiness. Instrumental and sensory data were included in this study to serve as an external data set to further explain the intrinsic factors that drive consumers' apple preferences.

The sensory data for each attribute were subjected to a three factor analysis of variance (ANOVA) using treatments, 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 samples' sensory attributes. Treatment attributes were therefore averaged across replicates and panellists. Instrumental data for TSS, TA, TSS/TA, firmness and DMC were subjected to one-way analysis of variance, with storage duration as main effect. Cultivars and seasons were analysed separately.

In order to compare the consumer characteristics that contributed to consumers' preference for eating quality and appearance in 2013, these characteristics were subjected to a 5 x 3 x 2 x 2 factorial ANOVA with factors, shelf-life duration (0, 7, 14, 21 and 28 days for 'GD' and 0, 3, 7, 14 and 21 days for 'TR'), ethnic group (black, coloured and white), age group [(young (18-25), older (26+)] and gender (male and female). In order to compare the consumer characteristics that contributed to consumers' preference for eating quality and appearance in 2014, these characteristics were subjected to a 4 x 3 x 2 x 2 factorial ANOVA with factors, shelf-life duration (0, 9, 18 and 27 days for 'GD' and 'TR', respectively), ethnic group (black, coloured and white), age group [(young (18-25), older (26+)] and gender (male and female). In both 2013 and 2014, the four factor ANOVA model was also applied to the analyses of conceptual preferences, where consumer liking for conceptually tested attributes was taken as the dependent variables. SAS statistical software (SAS, version 9, 1999, Cary, North Carolina, USA) was used for the analyses. Statistical significance was defined at $P\leq0.05$. Student's t-LSD's (Least Significant Difference) were calculated at a 5%

significance level and used to determine whether preference for eating quality and appearance differed significantly between different gender, age and ethnic groups.

Principal component analysis (PCA) was performed in order to study the data structure and the association between the sensory attributes and consumer characteristics (gender, age and ethnic group) that contributed significantly to consumer preference. In order to reduce variation and the number of points on the corresponding figures, mean values of the liking scores were calculated for combinations of ethnic_group*treatment, age_group*treatment and gender*treatment. These means, together with the sensory means and the corresponding number of observations, were taken as input to a PCA based on the correlation matrix. Means for ethnic_group*treatment, age_group*treatment and gender*treatment were projected onto separate PCA spaces. To measure the linear relationship between the sensory attributes and consumer liking, Pearson's correlation coefficients were calculated for each of the different age and ethnic groups (Pèneau *et al.*, 2006). A similar PCA was performed in order to study the effect of ethnic group, age group and gender on consumers' preference for apple appearance. All multivariate analyses were conducted using XLStat (Addinsoft, Version 2014, Paris, France).

Results

In order to ensure clarity in reporting this part of the study, "preference for texture quality" indicates a consumer's degree of liking for the overall texture of apples and "preference for taste quality" indicates a consumer's degree of liking for the overall flavour of apples, where the term "flavour" includes sweet taste, sour taste and the retronasal aroma volatiles (Rowan *et al.*, 2009). "Preference for appearance" indicates how consumers liked the overall colour and shape of the fruit.

Consumers tasted all apple samples to give an indication of "preference for texture quality", "preference for taste quality" and viewed life-sized colour photographs of representative apples to indicate "preference for appearance", which will be referred to as "actual evaluation". Preference for specific aspects of eating quality (e.g. crisp crunchy texture, soft ripe texture, juiciness etc.) was also evaluated conceptually, to determine conceptual factors that impact on consumers' preference for apple quality.

Sample attributes

For the sake of readability and brevity, only the most pertinent differences in sensory and instrumental sample attributes will be reported here. Astringency, bitterness with peel as well as toughness of peel did not differ between treatments (data not presented). A strong correlation was found between sensory hardness, crispness and crunchiness. Therefore, only sensory hardness will be presented.

Instrumental measurements

Golden Delicious (GD)

In 2013, the 'GD' treatments did not differ significantly in TSS, TSS/TA and DMC from Day 0 to Day 28 of shelf-life at 21 °C and 15 weeks in cold storage at -0.5 °C, respectively (Table 2). However, on Day 7, fruit had the highest mean TA value and it was significantly higher than fruit on Day 14 and Day 28 respectively. On Day 0, fruit TA was non-significantly different from fruit on Day 7 but also fruit on Day 21 and 28 respectively. On Day 0 fruit had the highest score for firmness, but it was not significantly firmer than fruit on Day 7 and 14, resectively. On Day 21 fruit had the lowest score for firmness, but it was not significantly lower than fruit on Day 14 and 28, respectively. On Day 28 fruit was significantly more yellow according to the colour chart than all treatments except for fruit on Day 21. On Day 0 fruit were significantly greener than all the other treatments.

In 2014, the 'GD' treatments did not differ significantly in TSS and DMC (Table 2) from Day 0 to Day 21 of shelf-life at 21 °C and 14 weeks in cold storage at -0.5 °C. On Day 0 fruit had the highest mean TA, which was significantly higher than fruit on Day 18 and 27, respectively. On Day 27 fruit had a significantly higher TSS/TA value than all the other treatments. On Day 0 fruit had the lowest TSS/TA value, but not significantly lower than fruit on Day 9. On Day 0 fruit was significantly firmer than all the other treatments, except for fruit on Day 27. On Day 27 fruit was significantly more yellow while fruit on Day 0 was significantly greener than all the other treatments.

Topred (TR)

The 2013, 'TR' treatments did not differ significantly in TSS, TSS/TA, firmness, DMC, Lightness and Chroma values (Table 3) from Day 0 to Day 21 and 10 weeks of cold storage

at -0.5 °C. On Day 0 fruit mean TA was significantly higher than fruit on Day 3 and Day 7, respectively but not significantly higher than fruit on Day 14 and 21, respectively (Table 3). Although, on Day 3 fruit had the highest hue angle, it was only significantly higher than fruit on Day 0.

In 2014, after 9 weeks of cold storage at -0.5 °C and Day 27 of shelf-life at 21 °C 'TR' had the highest mean TSS, but it was only significantly higher than fruit on Day 0 (Table 3). On Day 0 fruit had significantly higher TA, lower TSS/TA values and DMC, and was significantly firmer than all the other treatments. On Day 27, fruit had the lowest mean TA and firmness, as well as the highest TSS/TA, DMC and Chroma values, but did not differ significantly from fruit on Day 18. On Day 0 fruit had the lowest Chroma value, but not significantly lower than fruit on Day 9. On Day 18 fruit had the highest hue angle, but not significantly higher than fruit on Day 27.

Sensory profiles

Golden Delicious (GD)

The 2013 'GD' treatments did not differ significantly for sweet taste (Fig. 5). On Day 0, fruit was most sour while fruit on Day 28 were the least sour, but not significantly lower than fruit on Day 14 and 21, respectively. On Day 0, fruit had the highest mean score for apple flavour, but not significantly higher than fruit on Day 7, 14 and 21. On Day 28, fruit had the lowest mean score for apple flavour, but not significantly lower than fruit on Day 21. On Day 0 fruit had the lowest mean value for overripe fermented flavour, but not significantly lower than fruit on Day 7 and 14, respectively. On Day 28, fruit illustrated a slight overripe fermented flavour (mean score = 7.9). Considering textural attributes, fruit on Day 0 was perceived as the hardest and juiciest treatment, although it was not juicier than fruit on Day 7 (Fig. 5). On Day 21, fruit was perceived as the least hard and juicy and had the highest mean mealiness score of 22.6, but was not less juicy than fruit on Day 14 and 28, not softer than fruit on Day 7, 14 and 28 respectively, and not mealier than fruit on Day 14 and 28, respectively.

In terms of 2014 flavour attributes, 'GD' treatments did not differ significantly in sweet taste (Fig. 6). On Day 0 and 27 respectively, fruit were significantly more and less sour than fruit on Day 9 and 18. On Day 0, fruit had the highest apple flavour but was only significantly

higher than fruit on Day 27. On Day 27, fruit was significantly higher in overripe fermented flavour than all the other days. On Day 0, fruit had the lowest overripe fermented flavour, but was not significantly lower than fruit on Day 9 and 18, respectively. However, overripe fermented flavour was minimal and thus barely perceptible at a mean score of <4 for fruit on Day 27. In terms of textural attributes, on Day 0, fruit was perceived as the hardest, juiciest and least mealy treatment, but it was not significantly harder or mealier than fruit on Day 9 (Fig. 6). On Day 27, fruit was perceived as the softest, driest and most mealy treatment with a mealiness score of approximately 7.0, but it was not significantly softer than fruit on Day 18.

Topred (TR)

In terms of 2013 'TR' flavour attributes, fruit on Day 0 had the fruit with the highest mean sweetness, sourness, and apple flavour, as well as the lowest mean score for overripe fermented flavour, but did not differ significantly from fruit on Day 3 and 7 (Fig. 7). Fruit on Day 21 had the lowest mean sweetness and apple flavour, but not significantly lower than fruit on Day 14. On Day 21 fruit also had the lowest mean sourness, but not significantly less sour than fruit on Day 7 and 14 of ripening. On Day 21 fruit was significantly higher in overripe fermented flavour than all other treatments. In terms of textural attributes, on Day 0 'TR' was perceived as the hardest and juiciest treatment, although it was not significantly harder and juicier than fruit on Day 3 and 14 (Fig. 7). On Day 21 fruit had the highest mean mealiness score of 14.8 and it was mealier than all the other treatments, except for fruit on Day 7.

In terms of 2014 flavour attributes, on Day 0 'TR' had the highest sweetness, sourness, and apple flavour, as well as the lowest overripe fermented flavour. However, it was not significantly sweeter and sourer than fruit on Day 9 (Fig. 8). In terms of textural attributes, fruit on Day 0 was significantly harder and juicer than on all the other ripening Days (Fig. 8). On Day 0 fruit also had the lowest mean mealiness score of 0.16, but was not significantly different from fruit on Day 9. On Day 27 fruit was the softest, driest and most mealy with a mealiness score of 11.5, but was not softer or drier than fruit on Day 18.

Correlation analysis of sensory and instrumental attributes

Golden Delicious (GD)

In 2013, firmness showed a significant positive correlation with juiciness (r=0.95), but was negatively correlated with overripe fermented flavour (r=–0.96) and mealiness (r=–0.94) (Table 4). TSS correlated negatively with astringent mouthfeel (r=–0.90) while TSS/TA showed a significant positive correlation with mealiness (r=0.91) and negative correlations with sour taste (r=–0.90), overripe fermented flavour (r=–0.92) and juiciness (r=–0.90). Correlations between flavour and textural attributes showed that sour taste correlated positively with crispness, hardness, crunchiness and juiciness (r≥0.93 for all the correlations, but negatively with mealiness (r=–0.98) (Table 4). Overripe fermented flavour correlated positively with mealiness (r=0.89) but negatively with apple flavour (r=–0.95) and juiciness (r=–0.90). Crispness correlated significantly with hardness (r=0.98), crunchiness (r=0.99) and juiciness (r=0.95) but negatively with mealiness (r=–0.95) (Table 4).

For 'GD' in 2014, firmness did not correlate significantly with any other attribute (Table 5). TSS correlated negatively with sour taste (r=–0.97) and juiciness (r=–0.97). TA correlated positively with apple flavour, crispness, hardness and crunchiness (r>0.99 for all the correlations), as well as with juiciness (r=0.95) TSS/TA showed a positive correlation with mealiness (r=0.97), but correlated negatively with apple flavour, crispness, hardness, crunchiness and juiciness (r≥–0.97 for all the correlations). Correlations between flavour and texture attributes showed that apple flavour correlated positively with crispness, hardness, crunchiness and juiciness (r=0.99 for all the correlations) but negatively with mealiness (r=–0.97) (Table 5). Sour taste correlated significantly with juiciness (r=0.97). Crispness correlated significantly with hardness, crunchiness and juiciness (r≥0.96) but negatively with mealiness (r=–0.95). Hardness correlated significantly with crunchiness (r=0.99) and juiciness (r=0.98). Crunchiness correlated significantly with juiciness (r=0.96) but negatively with mealiness (r=–0.96) (Table 5).

Topred (TR)

In 2013, firmness correlated positively with sour taste (r=0.92) and negatively with overripe flavour (r=–0.96) (Table 6). TA correlated positively with peel toughness (r=0.93), while DMC correlated negatively with apple flavour (r=–0.96) and sweet taste (r=–0.95).

Correlations between flavour and texture attributes showed that apple flavour correlated significantly with sweet taste (r=0.99) (Table 6). Sweet taste and sour taste correlated negatively with overripe fermented flavour (r=–0.88 and r=–0.96). Crispness correlated significantly with hardness (r=0.99), crunchiness (r=0.99) and juiciness (r=0.91) but negatively with mealiness (r=–0.93). Hardness correlated significantly with crunchiness (r=0.99), juiciness (r=0.93) but negatively with mealiness (r=–0.93). Crunchiness correlated significantly with juiciness (r=0.94) but negatively with mealiness (r=–0.95). Similarly, juiciness correlated negatively with mealiness (r=–0.98) (Table 6).

The correlation matrix among the variables for the 2014 'TR' showed a positive correlation for firmness with crunchiness (r=0.96), as well as for TA with crispness (r=0.96), hardness (r=0.97), crunchiness (r=0.98) and juiciness (r=0.97) (Table 7). TSS, TSS/TA and DMC correlated negatively with apple flavour, crispness, hardness, crunchiness and juiciness (r≥–0.96 for all the correlations). Apple flavour correlated positively with sweet taste, sour taste, crispness, hardness, crunchiness and juiciness (r≥0.98 for all the correlations) but negatively with mealiness (r=–0.96) (Table 7). Sweet taste correlated significantly with sour taste, hardness, crunchiness and juiciness (r≥0.95 for all the correlations). Sour taste correlated significantly with crispness, hardness, crunchiness and juiciness (r≥0.95 for all the correlations). Overripe fermented flavour correlated significantly with mealiness (r=0.97). Crispness correlated positively with hardness, crunchiness and juiciness (r=0.99 for all the correlations) but negatively with mealiness (r=–0.96). Hardness correlated significantly with crunchiness (r=0.99) and juiciness (r=0.99) but negatively with mealiness (r=–0.95). Crunchiness correlated significantly with juiciness (r=0.99) (Table 7).

Principal component analyses (PCA) were conducted to ascertain the overall association between sensory attributes and instrumental measurements for both cultivars and seasons (Figs. 9, 10, 11 & 12). According to the 2013 'GD' PCA bi-plot (Fig. 9), the first and second principal components (PC 1 and PC 2) accounted for 66.4% and 17.9% of the variability in treatments attributes, respectively. Mealiness and overripe fermented flavour associated with fruit on Day 21 and Day 28 on PC 1 while sour taste, hardness, juiciness, crunchiness, crispness and apple flavour associated with fruit on Day 0. TSS associated with fruit on Day 21 and TSS/TA associated with fruit on Day 28. On Day 0, 'GD' fruit dissociated from

overripe fermented flavour and mealiness. TSS associated with fruit on Day 21 along PC 2 while TSS/TA associated with fruit on Day 14 and Day 28. On Day 14, 'GD' fruit dissociated from toughness of peel and TA along PC 2 while fruit on Day 21 dissociated from astringency.

PC 1 and PC 2, respectively accounted for 75.1% and 16.0% of the variability in the 'GD' attributes on the 2014 'GD' PCA bi-plot (Fig. 10). Fruit on Day 0 and 27 explained the variability on PC 1. On Day 0, fruit associated with hardness, crispness, crunchiness, juiciness, sour taste, apple flavour and TA while it dissociated from sweet taste, mealiness, overripe fermented flavour, TSS/TA, TSS and DMC. On Day 27 fruit associated with mealiness, overripe fermented flavour, TSS/TA, TSS and DMC.

With reference to the 2013 'TR' PCA bi-plot, PC 1 and PC 2 accounted for 55.4% and 24.7% of the variability in treatments attributes, respectively (Fig. 11). Fruit on Day 0 and 21 explained the variation on PC 1, while toughness of peel, TSS and TA separated from all other attributes on PC 2. Crispness, hardness, crunchiness, apple flavour, sweet taste and sour taste associated with fruit on Day 0 while bitterness, mealiness and overripe fermented flavour dissociated with fruit on Day 0 on PC 1. In contrast, on Day 21, fruit associated closely with mealiness, overripe fermented flavour and bitterness. On Day 3, fruit associated with firmness on PC 2, but dissociated from overripe fermented flavour.

According to the PCA bi-plot (Fig. 12), PC 1 and PC 2 accounted for 94.2% and 3.9%, respectively of the 2014 variability in 'TR' attributes. Crunchiness, juiciness, hardness, crispness, apple flavour, sour taste, sweet taste, firmness and TA associated with fruit on Day 0 while fruit on Day 18 and 27 associated with mealiness, overripe fermented flavour, TSS/TA, TSS and DMC on PC 1.

Consumer characteristics

In 2013, the total consumer group (n=450) comprised of 23% black, 34% coloured and 43% white consumers (Table 8). Sixty-seven percent of the consumers were aged between 18 and 25 (young age group) and 33% were 26 years or older (older age group). Black and white

consumers were underrepresented in the older age group. Sixty-three percent of the consumers were female and 37% were male. Black male consumers were also underrepresented. Sixty-four percent of the consumers eat apples frequently (2 to 3 times a week), while 36% consume apples less frequently (once a month). Black consumers who eat apples less frequently were underrepresented.

In 2014, the total consumer group (n=240) comprised of 17% black, 33% coloured and 50% white consumers (Table 9). Sixty-two percent of the consumers were aged between 18 and 25 (young age group) and 38% were 26 years and older (older age group). Black consumers were underrepresented in both age groups. Sixty-four percent of the consumers were female and 36% were male. Black male consumers were also underrepresented. Fifty-nine percent of the consumers eat apples frequently (2 to 3 times a week), while 41% consume apples less frequently (once a month). Black consumers who eat apples less frequently were underrepresented.

Seventy-two percent of the participating consumers in 2014 indicated that they prefer apples with a hard and very crisp texture, 24% like slightly soft and ripe apples and only 4% had a predilection for soft and slightly mealy apples. Black and white consumers who prefer slightly soft and ripe, as well as soft and slightly mealy apples were underrepresented. Coloured consumers who had predilection for soft and slightly mealy apples were also underrepresented.

Consumer groupings

Grouping based on ethnic, gender and age groups

Consumers' preference for texture and taste quality

There were no significant interactions for consumers' liking of both texture and taste quality of 'GD' fruit with varying shelf-life duration (Day) in either 2013 or 2014 (Table 10). In 2013, on Day 0 and 7 'GD' fruit had a significantly higher mean texture preference score than for fruit of all the other shelf-life durations (Table 11). On Day 28, fruit had a significantly lower texture preference score than for fruit on all the other shelf-life durations. Consumers preferred the taste of Day 7 fruit significantly more than the other shelf-life

durations. Fruit on Day 0 was preferred in taste to fruit on Day 21 and 28. The taste of Day 28 'GD' fruit was preferred significantly less than all other. In 2014, consumers gave a significantly lower mean texture and taste preference score for Day 27 'GD' (Table 11). Mean texture and taste scores for the preceding days did not differ significantly.

For 'TR' in 2013, *ethnic group* and *age group*, as well as, *ethnic group* and *gender* interacted significantly with consumers' liking for texture quality over the shelf-life duration (*Day*) (Table 12). *Ethnic group* interacted significantly with consumers' liking for taste quality over the shelf-life duration (*Day*). Textural quality preferences generally seemed to decrease with increasing shelf-life duration, except for older black and older coloured consumers whose textural quality liking did not differ significantly for any of the shelf-life durations (Fig. 13). Consequently, older black consumers liked the texture of Day 7 and 21 'TR' significantly more than young black consumers while older coloured consumers liked the texture of Day 7, 14 and 21 'TR' significantly more than younger coloured consumers (Fig. 13). The textural liking of young and older white consumers decreased with increasing shelf-life duration, but young consumers gave significantly higher scores than older consumers on Day 3 and 14. Young consumers of all three ethnicities liked the texture of 'TR' less than older black and coloured consumers on Day 21. Young consumers showed a significant decrease in their liking of texture quality compared to Day 0 from Day 7 while older white consumers showed a decrease from Day 3. Black and coloured male consumers did not show a decrease in 'TR' texture liking over time while female and white male consumers showed a decrease (Fig. 14). For white and coloured female consumers, the decrease in liking compared to Day 0 became significant by Day 7 while for black female consumers it become significant by Day 14. For white and female consumers, liking scores were equally low for Day 14 and 21. For 'TR' in 2014, texture quality preference decreased with increasing shelf-life duration for all three ethnic groups (black, coloured and white) (Fig 15). The decrease in preference in texture for all three ethnic groups was significant for each shelf-life to the next, except for from Day 18 to 27 for coloured consumers. Coloured consumers preferred the texture quality at Day 0 compared to white consumers and also at Day 27 compared to both black and white consumers. White consumers liked the texture quality of Day 18 significantly less compared to black and coloured consumers.

The taste liking for 'TR' in 2013 also generally decreased with increasing shelf life duration for all three ethnic groups (Fig. 16). The taste quality liking for Day 7, Day 14 and Day 21 did not differ significantly for coloured consumers while it also did not differ between Day 14 and 21 for white consumers. Coloured consumers preferred the taste quality of Day 21 significantly more compared to black and white consumers while white consumers preferred Day 14 significantly less than black and coloured consumers. For 'TR' in 2014, taste quality preferences generally seemed to decrease with increasing shelf-life duration except for older male consumers who showed a similar liking for Day 9, 18 and 27 shelf life durations (Fig. 17). Older male consumers liked the taste quality of Day 18 significantly more than female and young male consumers while they also showed a higher preference for Day 27 compared to female consumers. Young female consumers liked the taste quality of Day 27 significantly less than young male consumers and they also liked Day 0 taste quality less than all male consumers. Taste quality preferences generally seemed to decrease with increasing shelf life duration for all ethnic and age groups (Fig. 18). Older coloured consumers preferred the taste quality of Day 0 compared to young black and older white consumers, Day 9 compared to old black and old white consumers, Day 18 compared to all except young black consumers, and Day 27 compared to white and young black consumers. Older white consumers liked Day 0 taste quality less than all except young black consumers, Day 9 less than young black and old coloured consumers, Day 18 less than black and old coloured consumers, and Day 27 less than all except young white consumers.

Preference for appearance

For 'GD' in 2013, *ethnic group* and *age group*, as well as, *gender* interacted significantly with consumers' appearance preference (Table 10). For 'GD' in 2013, appearance preferences generally seemed to decrease with increasing shelf-life duration from a high liking at Day 0 to a definite dislike by Day 28, except for older coloured consumers whose appearance liking was only slightly lower for Day 0 and 28 compared to Day 14 and 21 (Fig. 19). Appearance liking decreased markedly and significantly from Day 7 to 14 for all except older coloured consumers and again from Day 21 to 28 (yellowest peel colour) for all except for older coloured consumers who only showed a small significant decrease. Young white consumers liked the appearance of 'GD' 28 significantly less than all other consumers. Older black consumers had a higher liking for Day 14 and 21 appearance compared to all except

older coloured consumers and also for Day 28 compared to white and young black consumers.

The appearance preference of male and female consumers for 2013 'GD' decreased significantly for each shelf-life duration to the next, except between Day 0 and 7 for female consumers (Fig. 20). Female consumers showed a significantly greater dislike for the Day 28 appearance compared to male consumers.

For 'GD' in 2014, *ethnic group* and *gender* interacted significantly with consumers' appearance preference (Table 10). For 'GD' in 2014, appearance preferences generally decreased with increasing shelf-life duration, especially for white and black female consumers but less so for coloured and black male consumers (Fig. 21). Except for black male and coloured male consumers, all consumers showed a significant decrease in preference from Day 0 to 9, but not with longer shelf-life durations. White male and white female consumers again showed a significant decrease in the appearance preference from Day 9 to 18. The preference of black female consumers did not decrease significantly from day 9 to 18, but unlike other consumers, they did show a significant decrease from Day 18 to 27. White female consumers significantly disliked the appearance of Day 21, and also Day 27 'GD' with the exception of black female consumers, compared to the other consumer groups. Black male and coloured female consumers significantly preferred the Day 27 appearance compared to white and black female consumers.

For 'TR' in 2013, *age group,* as well as *gender* interacted significantly with consumers' appearance preference (Table 12). For 'TR' in 2013, young (18-25) consumers showed a lower preference than older consumers (26+) for the appearance of 'TR' of all shelf-life durations (Fig. 22). Both age groups as well as both genders (Table 23) preferred Day 0 fruit to other shelf life durations. Except for Day 0 and 14, female consumers preferred the appearance of all shelf-life durations significantly less than male consumers. Female consumers preferred fruit from shelf-life durations of 3 days and longer similarly. Male consumers showed a lower preference for Day 14 compared to Day 0, 3 and 21 fruit (Fig. 23). For 'TR' in 2014, *ethnic group* interacted significantly with consumers' appearance preference (Table 12). In 2014, black consumers significantly preferred the appearance of

Day 0 fruit compared to coloured and white consumers while white consumers had a significantly lower appearance preference for Day 27 fruit compared to black and coloured consumers (Fig. 24). Black consumers showed a higher preference for Day 0 fruit, white consumers showed a lower preference for Day 27 fruit and coloured consumers preferred fruit of all shelf life durations similarly.

Conceptual preference for eating quality attributes

The factors *ethnic group* and *age group* interacted significantly with consumers' conceptual preference of sensory attributes for the 2013 and 2014 study, respectively (Table 13). In 2013, consumers generally gave high preference scores for very juicy (scores ranged from 7.3 to 7.9), crisp, crunchy texture (7.2 to 8.4), sweet taste (7.2 to 8.0) and prominent apple flavour (6.1 to 7.8) while astringent mouthfeel (scores ranged from 1.9 to 3.4), slight bitter taste (2.4 to 3.4), slight mealy texture (2.1 to 4.3), high degree of mealiness (1.3 to 3.5) and spongy texture (2.2 to 4.3) were generally scored lowest (Fig. 25). Different consumer groups appeared to have similar preferences for very juicy, moderately juicy and sweet taste as well as comparable dislikes for slight bitter taste. Crisp crunchy texture seemed to be of greater importance for white consumers while they also showed a higher preference compared to other consumer groups for prominent apple flavour and sour taste except for older black consumers and young coloured consumers, respectively. Older coloured consumers minded a high degree of mealiness, spongy texture and soft, ripe texture significantly less than other consumer groups. They even expressed a slight liking for soft, ripe texture. They also minded a slight mealy texture less than other consumers, except for young black consumers. White consumers indicated a significantly greater dislike of slight and high degree of mealiness compared to other consumer groups.

In 2014, consumers generally gave high to intermediate preference scores for sweet taste (scores ranged from 6.7 to 8.1), crisp, crunchy texture (7.1 to 8.3), very juicy (6.9 to 7.6), prominent apple flavour (5.9 to 7.8) and moderately juicy (5.7 to 6.9) (Fig. 26). Low to intermediate preference scores were given for sour taste (scores ranged from 3.5 to 6.4) and soft ripe texture (3.4 to 5.3) while slight mealy texture received low scores (1.9 to 3.8). Consumer groups did not differ in their scores for very juicy. White consumers gave higher scores for crisp, crunchy texture compared to older coloured consumers and also, together

with young coloured consumers, higher scores for sour taste compared to other groups. White consumers indicated a greater dislike for slight mealy texture, but the difference between older white and young coloured consumers was not significant. Older coloured consumers gave a higher liking score to slight mealy texture compared to other consumers, except for young black consumers. They also scored moderately juicy lower than black consumers. Older black consumers' preferred sweet taste compared to all groups except for young black and older coloured consumers. Young black consumers preferred sour taste the least, but not significantly less than older coloured consumers. Prominent apple flavour was also of lesser importance to them compared to white and older black consumers.

Discussion

Physical and sensory changes in relation to maturity levels

'GD' fruit in both 2013 and 2014 showed a general yellowing, a decrease in acidity, sour taste, hardness and juiciness, as well as an increase in overripe fermented flavour and mealiness with increasing shelf-life duration. These textural, flavour and appearance changes, although not very substantial in our study, are typical of ripening apples (Jaeger *et al*., 1998; Richardson-Harman *et al*., 1998; Varela *et al*., 2005). Jaeger *et al*. (1998) found that fresh apples were generally perceived as being more crisp, hard and juicy, while ripe apples were soft and mealy. Richardson-Harman *et al*. (1998) indicated that apple fruit with a green ground colour are associated with firmness, while apple fruit with a yellow ground are associated with softness and mealiness. 'TR' fruit showed similar ripening-associated changes in texture and flavour in 2014, but not so much in 2013. Various factors such as stage of maturity (Harker *et al*., 1997, Richardson-Harman *et al*., 1998, Steyn, 2012), cold storage conditions and duration (Harker *et al*., 1997, Soliva-Fortuny *et al*., 2002; Varela *et al*., 2005), as well as shelf-life duration can affect progression of ripening in apples. 'TR' apples in 2013 seemed to ripen at a much slower rate compared to 2014 and compared to 'GD', which probably explains why instrumental firmness did not correlate significantly with any sensory textual attribute. Yellowing of the peel was not discernible in 'TR', but the colour became slightly less red and more saturated over the shelf-life period. However, peel colour change in 'TR' was much less conspicuous compared to 'GD' (Figs. 1-4). The recommended firmness for 'GD' at harvest is 7.8 kg while firmness for 'TR' at harvest is 8.0 kg (HORTGRO, 2015). The firmness of 'GD' apples at the onset of the experiment ranged from 3.9 to 4.3 kg in 2013 and from 3.9 to 4.2 kg in 2014. Fruit firmness for 'TR' apples

ranged from 4.9 to 5.7 kg in 2013 and from 4.1 to 5.2 kg in 2014. The generally low firmness of both cultivars at the onset of the experiment in both seasons may have led to smaller changes in the levels of the various ripening-associated attributes over the shelf-life period than might otherwise have been the case.

The high positive correlation between instrumental firmness and sensory juiciness, as well as the negative correlation of instrumental firmness with overripe flavour and mealiness for 'GD' fruit in 2013 concurs with findings of Jaeger *et al*. (1998), Harker *et al*. (2002a), Brookfield *et al*. (2011) and Bonany *et al*. (2014). There was no significant correlation between instrumental firmness and any related sensory attribute for 'GD' fruit in 2014, probably because firmness changed little during shelf-life while sensory changes were more pronounced. Instrumental firmness correlated strongly with sour taste in 'TR'. This is in agreement with our study (Paper 1) and previous research findings (Harker *et al*., 2002a; Bonany *et al*., 2014). A strong negative correlation existed between instrumental firmness and overripe flavour for 'TR' fruit in 2013. This concurs with findings of Jaeger *et al*. (1998).

Mealiness correlated negatively with hardness in both cultivars and seasons. Significant negative correlations were also found with juiciness (both cultivars in 2013), apple flavour (both cultivars in 2014) and sourness ('GD' in 2013) while mealiness also correlated positively with TSS/TA ('GD') and over-ripe flavour ('GD' in 2013 and 'TR' in 2014). Jaeger *et al*. (1998) and Varela *et al*. (2005) found that mealiness was closely associated with off-flavours, ripe flavour, as well as, alcoholic flavour and odour. Mealiness correlated positively with overripe fermented flavour and TSS/TA (Jaeger *et al*., 1998), but negatively with apple flavour (Jaeger *et al*., 1998), juiciness, sour taste and hardness (Harker *et al*., 2002a, Bonany *et al*. 2014, Paper 1).

Contrary to findings of Harker *et al*. (2002b), Bonany *et al*. (2014) and Paper 1 of our study, TSS was not a good predictor for the sensory attribute sweet taste in both cultivars and seasons. Likewise, correlations between TA and sour taste were also not significant. This is despite Harker *et al*. (2002b) indicating that TA is the best predictor of sour taste and strong correlations in other studies (Bonany *et al*., 2014; Thiault, 1970; Paper 1). Palmer *et al*. (2010) showed that DMC proved a consistent predictor of TSS and was highly correlated

with firmness, but in our study DMC only correlated positively with TSS for 'GD' fruits in 2014. In other instances, DMC either did not correlate with any instrumental measurements and sensory attributes ('GD' in 2013) or correlated negatively with some sensory attributes (apple flavour and sweet taste for 'TR' in 2013 and flavour and crispness for 'TR' in 2014). Cronjé *et al*. (2015) also did not find a correlation between DMC and eating quality in 'Forelle' pears. However, Hamadziripi *et al*. (2014) found significant correlations between DMC and eating quality preference for outer canopy 'Starking', 'Golden Delicious' and 'Granny Smith' apples.

Actual preference for eating quality

Consumer preference for 'GD' texture and taste showed a slight decline with increasing shelf-life in both seasons, but there was no segregation in terms of ethnic or age group. This was possibly due to the slight differences in firmness, no significant differences in TSS and slight differences in acidity as the fruits ripened. Contrary to recommendation of Harker *et al*. (2002a), the firmness values of 'GD' treatments used in our study did not vary widely enough for texture differences to be detected despite the long shelf-life duration. Firmness differences might have been larger if fruit were not already somewhat soft at the onset of the experiment. The slight decline in consumers' preference of the texture and taste quality of 'GD' treatments as fruits ripened seem to concur with Palmer *et al*. (2010) who found that consumers generally prefer crisp and juicy apple fruit and a repeated purchase is almost assured when apples stay crisp and juicy.

Older black, older coloured as well as black male and coloured male consumers liked the texture quality of 'TR' apples in 2013 irrespective of ripeness level and showed a higher preference for riper apples compared to other consumer groups. In 2014, when differences in the sensory attributes of 'TR' apples were much more pronounced, coloured consumers of all ages preferred the texture quality of the riper, softer and more mealy 'TR' apples compared to black and white consumers. These results are generally in agreement with previous indications that older black and coloured consumers (Van der Merwe, 2013; Paper 1) as well as male consumers of these two groups (Paper 1) that have a greater tolerance for mealiness. It is also consistent with the indication by older coloured consumers that they have a greater liking for a soft ripe texture, slight and high degree of mealiness as well as a spongy texture

compared to the other consumer groups. Van der Merwe (2013) showed that black and coloured consumers preferred sweet tasting apples and tolerated mealiness. Black consumers in our study (Paper 1) revealed a similar preference pattern. However, black consumers seemed to dislike the eating quality of ripe 'TR' apples to the same extent as white consumers. Older black consumers seem to have a high preference for sweet taste rather than having a preference for a soft, mealy texture (Paper 1), which would explain why they seem to have had a lower tolerance for the characteristics of ripe 'TR' apples compared to older coloured consumers in 2014. Hence, the apparent tolerance of black consumers for mealiness in the study by Van der Merwe (2013), as well as in Paper 1 of our study, is not because they like mealy apples, but is due to their generally very high preference of sweet taste and the sweet tasting cultivars. According to Fushan *et al*. (2009), Sub-Saharan African populations have the tendency to prefer higher sweetness levels because of the reduced taste sensitivity to sucrose among such populations. Previously, Jaeger *et al*. (1998) found no difference between British and Danish consumers in preference of apple fruit with varying mealiness levels. Daillant-Spinnler *et al*. (1996) and Symoneaux *et al*. (2012) also found that European and French consumers, respectively, disliked mealiness and considered it a negative attribute. Similarly, young consumers, as well as older white consumers showed a greater dislike for the eating quality of 'TR' fruit as they ripen. This preference pattern is apparent in young and white consumers' general higher conceptual preference indication for crisp crunchy texture, as well as sour taste. Older black and older coloured consumers seemed to have a higher threshold for the textural and eating quality attributes characteristic of riper apples compared to young and older white consumers who indicated a strong aversion to soft ripe texture, sponginess and mealiness. Carbonell *et al*. (2008) and Seppä *et al*. (2013) identified groups of Spanish and Finnish consumers, respectively, that preferred either firm and sour, or medium sweet and medium sour or sweet and soft/mealy apples. Except for black female consumers, female consumers generally had a greater dislike of 'TR' fruits as they ripened. Coloured female consumers having similar preference pattern with white consumers concurs with findings of Viljoen and Gericke (2001) who found that coloured and white consumers had similar food preferences that could be described as European-like.

Preference for appearance

The higher preference of older coloured consumers, as well as male consumers for more yellow compared to greener 'GD' apples compared to other consumer groups is consistent

with their generally greater preference compared to other consumers for riper, softer and mealier apples and agrees with previous findings (Van der Merwe, 2013; Paper 1). Likewise, young consumers and white consumers in general preferred the greener appearance of less ripe 'GD' apples to the riper and more yellow apples, which correlates with their general eating quality preference for crisp, firm and sour apples. Interestingly, there was no segregation in terms of ethnic and age group preferences for the eating quality of 'GD' apples in 2013 and 2014, which we ascribed to relatively small changes in the sensory profile of these fruit over the duration of the trial. Ground colour changed comparatively much more in both 2013 and 2014 over the duration of the trial. Hence, the yellowing that was observed over the duration of the trial did not reliably indicate fruit eating quality. According to Lau (1988), Kingston (1992), Richardson-Harman *et al*. (1998) and Steyn (2012), the yellowing of fruit ground colour is usually a very good indicator of maturity and as such in apple associates with sweet taste, as well as with soft and soft-related comments. On the other hand, green colour in apples is associated with firmness (Richardson-Harman *et al*., 1998).

The higher preference of older consumers as well as male consumers for the appearance of riper 'TR' apples is consistent with their generally greater preference for riper and sweeter fruit and agrees with previous findings (Van der Merwe, 2013; Paper 1). Clydesdale (1993) showed that red peel colour associates with sweet taste and Steyn (2012) ascribed this taste and colour association to the fact that as fruit ripen, they generally increase in both red colouration and sweetness. The general dislike of white consumers of 'TR' fruit compared to black and coloured consumers is consistent with their generally greater preference for crisp and firm apples. Red apple peel colour is associated with sweet taste and perceived to be more mature, whereas green apple peel colour is perceived to be sour, crisp and firm (Clydesdale, 1993; Daillant-Spinnler *et al*., 1996; Richardson-Harman *et al*., 1998; Shankar *et al*., 2010). The external colour of 'TR' apples was also not indicative of the fruit's internal quality, but for another reason than in 'GD'. In the case of 'TR', internal quality changed considerably during the shelf-life period, particularly in 2014. However, the appearance of the fruit changed comparatively little because ground colour change was largely masked by the overlaying anthocyanins. Steyn (2012) discussed the difficulty of assessing fruit maturity in fruits where ground colour change is obscured. Unlike in 'GD' where consumers may consider fruit over-mature based on appearance while internal quality might still be good, in 'TR', consumers do not have a reliable means to decide which fruit to purchase at any given

time that would satisfy their specific eating quality preferences. Therefore, basing consumers eating quality expectations of 'TR' fruit on its peel colour can be misleading and would explain why consumers who prefer crisp apples would rather shun fruit of this cultivar even though it may meet their eating quality preferences at early stages of ripening.

Conclusions

Results from our study showed ethnic, age and gender differences in consumer preference of apple fruit with varying maturity or ripeness levels. Coloured consumers, but more specifically older coloured consumers, did not show a similar decrease in preference for the eating quality characteristics of riper, softer and mealy 'TR' or for the more yellow appearance of riper 'GD' apples as did black and white consumers. White, black and young consumers seemed to generally prefer the eating quality characteristics of greener, less ripe fruit. The threshold background colour at which 'GD' fruit is removed from shelves could be less strict in shops in predominantly coloured neighbourhoods. In addition, 'GD' fruit with a less green or yellower colour at harvest could be earmarked for such shops. Older black consumers are a target market for sweet apples but not for very ripe, overly soft and mealy apples as well as apples that may display these characteristics as indicated by yellow ground colour. Black and white consumers will generally not buy yellow 'Golden Delicious' fruit.

Male and coloured consumers could be targeted with 'Topred' fruit with a wide ripeness range irrespective of the shades of red. However, considering that female consumers are mostly responsible for apple purchasing (Paper 2), it would be difficult to target male consumers specifically. The full red peel colour of 'TR' does not allow the assessment of ripeness or the internal texture and taste quality of the fruit. Consumers who do not like the eating quality of ripe apples are therefore unlikely to purchase 'TR' apples even though they might like the eating quality of less ripe 'TR' fruit. If marketed to such consumers and if bought by them, 'TR' apples might be a source of consumer dissatisfaction. It would be interesting to study the satisfaction or dissatisfaction of different consumer groups with apple cultivars with different appearances and relate these results to repurchase decisions.

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Table 1 Descriptors of sensory attributes used for the sensory analysis of apple fruit (adapted from Daillant-Spinnler *et al*., 1996).

Attributes	**Description**	**Scale**
Sweet taste	One of basic tastes, e.g. sucrose	0 = None 100 = Prominent sweet taste
Sour taste	One of basic tastes, e.g. citric acid	0 = None 100 = Prominent sour taste
Apple flavour	Associated with typical apple flavour	0 = None 100 = Prominent apple flavour
Fermented flavour	Associated with overripe fermented apple flavour	0 = None 100 = Prominent fermented flavour
Astringency	Dries the surface of the mouth, i.e. tannic acid	0 = None 100 = Prominent astringency
Crispness	Sound generated when biting into apple with front teeth	0 = None 100 = Prominent crispness
Hardness	Force to bite into apple with molar teeth	0 = None 100 = Very hard
Crunchiness	Ease of disintegration when chewing with molar teeth	0 = None 100 = Prominent crunchiness
Juiciness	Amount of juice released by sample during chewing	0 = None 100 = Extremely juicy
Mealiness	Over-ripe soft, dry and floury texture	0 = None 100 = Prominent mealiness
Peel toughness	Measure of how tough the peel is	0 = None 100 = Prominent toughness

Table 2 Means of measured total soluble solids (TSS), titratable acidity (TA), calculated ratio of total TSS and TA (TSS/TA) and maturity indexes (firmness, dry matter concentration (DMC) and ground colour values – measure of yellowness underlying the green colour and excluding any blush) for 'Golden Delicious' in 2013 and 2014, respectively with varying self-life duration. Means with different alphabetical letters differ significantly. Means were separated by least significant difference (LSD) (5%).

Treatments	**TSS (°Brix)**	**TA (Malic acid %)**	**TSS/TA**	**Firmness (N)**	**DMC (%)**	**Ground colour**
2013						
Day 0	12.4 NS	0.20 ab	58.5 NS	42.1 a	28.5 NS	2.5 d
Day 7	13.1	0.21 a	61.4	41.6 a	30.3	3.3 c
Day 14	12.6	0.16 c	72.1	39.6 ab	31.9	3.9 b
Day 21	13.1	0.19 abc	70.1	37.8 b	29.5	4.5 a
Day 28	12.9	0.18 bc	76.8	38.7 b	29.8	4.6 a
P-value	***0.3616***	***0.0456***	***0.2449***	***0.0120***	***0.1879***	***<0.0001***
2014						
Day 0	12.4 NS	0.33 a	38.5 c	40.9 a	14.1 NS	3.1 d
Day 9	12.8	0.31 a	42.0 bc	39.2 bc	14.6	4.2 c
Day 18	12.7	0.28 b	45.6 b	38.0 c	14.3	4.6 b
Day 27	13.1	0.26 b	50.4 a	40.4 ab	14.8	4.9 a
P-value	***0.1082***	***<0.0001***	***<0.0001***	***0.0070***	***0.3053***	***<0.0001***

Table 3 Means of measured total soluble solids (TSS), titratable acidity (TA), calculated ratio of total TSS and TA (TSS/TA) and maturity indexes (firmness, dry matter concentration (DMC) and colorimeter values) for 'Topred' in 2013 and 2014, respectively with varying self-life duration. Means with different alphabetical letters differ significantly. Means were separated by least significant difference (LSD) (5%).

Treatments	TSS (°Brix)	TA (Malic acid %)	TSS/TA	Firmness (N)	DMC (%)	Blushed side		
						Lightness	Chroma	Hue (˚)
2013								
Day 0	13.9 NS	0.19 a	75.5 NS	53.3 NS	26.0 NS	31.8 NS	28.3 NS	19.8 b
Day 3	13.1	0.14 c	87.3	55.4	28.6	33.9	31.7	24.7 a
Day 7	13.8	0.15 bc	88.1	52.1	27.4	33.5	31.2	24.0 a
Day 14	13.8	0.17 ab	81.9	51.3	28.5	33.1	31.0	23.8 a
Day 21	13.7	0.17 ab	82.8	47.6	29.4	34.0	31.9	24.4 a
P-value	***0.1113***	***0.0075***	***0.5550***	***0.0765***	***0.0828***	***0.2632***	***0.2452***	***0.0204***
2014								
Day 0	12.7 b	0.31 a	41.0 c	51.3 a	13.6 c	34.6 NS	30.4 c	23.7 c
Day 9	13.5 a	0.26 b	53.6 b	44.0 b	14.8 b	35.1	31.8 bc	26.0 bc
Day 18	13.9 a	0.23 bc	59.7 ab	41.8 bc	15.5 ab	36.9	34.1 ab	30.0 a
Day 27	14.2 a	0.22 c	66.2 a	40.4 c	16.2 a	36.5	36.3 a	28.1 ab
P-value	***0.0035***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***0.1462***	***0.0014***	***0.0058***

Table 4 Correlation matrix variables (sensory and instrumental quality variables) included in principal component analysis for 2013 'Golden Delicious'

Variables	Apple flavour	Sweet	Sour	Overripe flavour	Crispness	Hardness	Crunchiness	Juiciness	Mealiness	Astringent	Peel toughness	TSS	TA	TSS/TA	Firmness	DMC
Flavour	**1**	-0.535	0.760	**-0.948**	0.626	0.559	0.598	0.785	-0.764	0.793	-0.020	-0.547	0.310	-0.813	0.860	0.100
Sweet	-0.535	**1**	-0.704	0.518	-0.411	-0.541	-0.454	-0.560	0.573	-0.220	-0.826	0.277	-0.528	0.753	-0.374	0.511
Sour	0.760	-0.704	**1**	-0.846	**0.930**	**0.946**	**0.938**	**0.975**	**-0.976**	0.716	0.267	-0.635	0.546	**-0.900**	0.866	-0.536
Overripe flavour	**-0.948**	0.518	-0.846	**1**	-0.755	-0.678	-0.726	**-0.902**	**0.892**	-0.732	0.022	0.443	-0.546	**0.916**	**-0.963**	0.126
Crispness	0.626	-0.411	**0.930**	-0.755	**1**	**0.976**	**0.997**	**0.954**	**-0.952**	0.775	-0.020	-0.693	0.422	-0.738	0.870	-0.519
Hardness	0.559	-0.541	**0.946**	-0.678	**0.976**	**1**	**0.990**	**0.925**	**-0.927**	0.702	0.172	-0.702	0.430	-0.733	0.777	-0.637
Crunchiness	0.598	-0.454	**0.938**	-0.726	**0.997**	**0.990**	**1**	**0.946**	**-0.945**	0.750	0.047	-0.699	0.426	-0.735	0.838	-0.568
Juiciness	0.785	-0.560	**0.975**	**-0.902**	**0.954**	**0.925**	**0.946**	**1**	**-0.999**	0.748	0.084	-0.587	0.575	**-0.900**	**0.948**	-0.466
Mealiness	-0.764	0.573	**-0.976**	**0.892**	**-0.952**	**-0.927**	**-0.945**	**-0.999**	**1**	-0.714	-0.112	0.556	-0.611	**0.909**	**-0.939**	0.504
Astringent	0.793	-0.220	0.716	-0.732	0.775	0.702	0.750	0.748	-0.714	**1**	-0.323	**-0.897**	-0.090	-0.504	0.781	0.100
Peel toughness	-0.020	-0.826	0.267	0.022	-0.020	0.172	0.047	0.084	-0.112	-0.323	**1**	0.118	0.426	-0.342	-0.162	-0.595
TSS	-0.547	0.277	-0.635	0.443	-0.693	-0.702	-0.699	-0.587	0.556	**-0.897**	0.118	**1**	0.297	0.296	-0.505	0.029
TA	0.310	-0.528	0.546	-0.546	0.422	0.430	0.426	0.575	-0.611	-0.090	0.426	0.297	**1**	-0.772	0.524	-0.664
TSS/TA	-0.813	0.753	**-0.900**	**0.916**	-0.738	-0.733	-0.735	**-0.900**	**0.909**	-0.504	-0.342	0.296	-0.772	**1**	-0.859	0.450
Firmness	0.860	-0.374	0.866	**-0.963**	0.870	0.777	0.838	**0.948**	**-0.939**	0.781	-0.162	-0.505	0.524	-0.859	**1**	-0.214
DMC	0.100	0.511	-0.536	0.126	-0.519	-0.637	-0.568	-0.466	0.504	0.100	-0.595	0.029	-0.664	0.450	-0.214	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 5 Correlation matrix variables (sensory and instrumental quality variables) included in principal component analysis for 2014 'Golden Delicious'.

Variables	Apple flavour	Sweet	Sour	Overripe flavour	Crispness	Hardness	Crunchiness	Juiciness	Mealiness	TSS	TA	TSS/TA	Firmness	DMC
Flavour	**1**	-0.426	0.916	-0.829	**0.991**	**0.995**	**0.994**	**0.985**	**-0.969**	-0.923	**0.985**	**-0.998**	0.196	-0.789
Sweet	-0.426	**1**	-0.752	0.320	-0.334	-0.452	-0.352	-0.573	0.287	0.687	-0.347	0.374	-0.224	0.838
Sour	0.916	-0.752	**1**	-0.732	0.871	0.926	0.881	**0.969**	-0.827	**-0.971**	0.874	-0.892	0.265	-0.938
Overripe flavour	-0.829	0.320	-0.732	**1**	-0.771	-0.773	-0.785	-0.830	0.923	0.867	-0.734	0.823	0.383	0.781
Crispness	**0.991**	-0.334	0.871	-0.771	**1**	**0.992**	**1.000**	**0.956**	**-0.953**	-0.864	**0.998**	**-0.996**	0.272	-0.702
Hardness	**0.995**	-0.452	0.926	-0.773	**0.992**	**1**	**0.994**	**0.982**	-0.941	-0.910	**0.992**	**-0.993**	0.289	-0.778
Crunchiness	**0.994**	-0.352	0.881	-0.785	**1.000**	**0.994**	**1**	**0.963**	**-0.958**	-0.877	**0.997**	**-0.998**	0.255	-0.720
Juiciness	**0.985**	-0.573	**0.969**	-0.830	**0.956**	**0.982**	**0.963**	**1**	-0.938	**-0.972**	**0.951**	**-0.973**	0.186	-0.880
Mealiness	**-0.969**	0.287	-0.827	0.923	**-0.953**	-0.941	**-0.958**	-0.938	**1**	0.891	-0.934	**0.972**	0.031	0.741
TSS	-0.923	0.687	**-0.971**	0.867	-0.864	-0.910	-0.877	**-0.972**	0.891	**1**	-0.852	0.901	-0.034	**0.963**
TA	**0.985**	-0.347	0.874	-0.734	**0.998**	**0.992**	**0.997**	**0.951**	-0.934	-0.852	**1**	**-0.990**	0.329	-0.691
TSS/TA	**-0.998**	0.374	-0.892	0.823	**-0.996**	**-0.993**	**-0.998**	**-0.973**	**0.972**	0.901	**-0.990**	**1**	-0.199	0.752
Firmness	0.196	-0.224	0.265	0.383	0.272	0.289	0.255	0.186	0.031	-0.034	0.329	-0.199	**1**	0.016
DMC	-0.789	0.838	-0.938	0.781	-0.702	-0.778	-0.720	-0.880	0.741	**0.963**	-0.691	0.752	0.016	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 6 Correlation matrix variables (sensory and instrumental quality variables) included in principal component analysis for 2013 'Topred'

Variables	Apple favour	Sweet	Sour	Overripe flavour	Crispness	Hardness	Crunchiness	Juiciness	Mealiness	Astringent	Bitterness	Peel toughness	TSS	TA	TSS/TA	Firmness	DMC
Flavour	**1**	**0.998**	0.832	-0.873	0.697	0.643	0.708	0.724	-0.759	-0.313	-0.593	-0.066	0.238	0.293	-0.398	0.698	**-0.959**
Sweet	**0.998**	**1**	0.830	**-0.882**	0.724	0.671	0.733	0.745	-0.787	-0.259	-0.551	-0.063	0.234	0.288	-0.389	0.710	**-0.949**
Sour	0.832	0.830	**1**	**-0.956**	0.670	0.664	0.718	0.878	-0.832	-0.086	-0.717	-0.314	-0.292	-0.004	-0.233	**0.917**	-0.669
Overripe flavour	-0.873	**-0.882**	**-0.956**	**1**	-0.662	-0.644	-0.698	-0.849	0.860	0.007	0.525	0.407	0.244	0.098	0.086	**-0.958**	0.702
Crispness	0.697	0.724	0.670	-0.662	**1**	**0.995**	**0.997**	**0.914**	**-0.931**	0.307	-0.292	0.358	0.200	0.538	-0.655	0.532	-0.602
Hardness	0.643	0.671	0.664	-0.644	**0.995**	**1**	**0.996**	**0.926**	**-0.932**	0.371	-0.276	0.347	0.131	0.505	-0.635	0.537	-0.530
Crunchiness	0.708	0.733	0.718	-0.698	**0.997**	**0.996**	**1**	**0.942**	**-0.947**	0.299	-0.341	0.308	0.135	0.497	-0.635	0.581	-0.598
Juiciness	0.724	0.745	0.878	-0.849	**0.914**	**0.926**	**0.942**	**1**	**-0.979**	0.297	-0.452	-0.001	-0.172	0.215	-0.418	0.802	-0.546
Mealiness	-0.759	-0.787	-0.832	0.860	**-0.931**	**-0.932**	**-0.947**	**-0.979**	**1**	-0.343	0.319	0.006	0.086	-0.208	0.368	-0.796	0.587
Astringent	-0.313	-0.259	-0.086	0.007	0.307	0.371	0.299	0.297	-0.343	**1**	0.616	0.016	-0.365	-0.196	0.187	0.140	0.493
Bitterness	-0.593	-0.551	-0.717	0.525	-0.292	-0.276	-0.341	-0.452	0.319	0.616	**1**	0.055	0.081	-0.231	0.450	-0.439	0.585
Peel toughness	-0.066	-0.063	-0.314	0.407	0.358	0.347	0.308	-0.001	0.006	0.016	0.055	**1**	0.745	**0.928**	-0.836	-0.588	-0.102
TSS	0.238	0.234	-0.292	0.244	0.200	0.131	0.135	-0.172	0.086	-0.365	0.081	0.745	**1**	0.805	-0.616	-0.507	-0.472
TA	0.293	0.288	-0.004	0.098	0.538	0.505	0.497	0.215	-0.208	-0.196	-0.231	**0.928**	0.805	**1**	**-0.955**	-0.340	-0.456
TSS/TA	-0.398	-0.389	-0.233	0.086	-0.655	-0.635	-0.635	-0.418	0.368	0.187	0.450	-0.836	-0.616	**-0.955**	**1**	0.130	0.505
Firmness	0.698	0.710	**0.917**	**-0.958**	0.532	0.537	0.581	0.802	-0.796	0.140	-0.439	-0.588	-0.507	-0.340	0.130	**1**	-0.473
DMC	**-0.959**	**-0.949**	-0.669	0.702	-0.602	-0.530	-0.598	-0.546	0.587	0.493	0.585	-0.102	-0.472	-0.456	0.505	-0.473	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 7 Correlation matrix variables (sensory and instrumental quality variables) included in principal component analysis for 2014 'Topred'.

Variables	Apple flavour	Sweet	Sour	Overripe flavour	Crispness	Hardness	Crunchiness	Juiciness	Mealiness	TSS	TA	TSS/TA	Firmness	DMC
Flavour	**1**	**0.976**	**0.977**	-0.876	**0.995**	**0.996**	**0.993**	**0.997**	**-0.964**	**-0.961**	0.942	**-0.967**	0.915	**-0.975**
Sweet	**0.976**	**1**	**1.000**	-0.793	0.950	**0.956**	**0.954**	**0.964**	-0.925	-0.900	0.880	-0.900	0.850	-0.912
Sour	**0.977**	**1.000**	**1**	-0.789	**0.951**	**0.958**	**0.957**	**0.966**	-0.923	-0.905	0.886	-0.905	0.857	-0.916
Overripe flavour	-0.876	-0.793	-0.789	**1**	-0.896	-0.873	-0.851	-0.858	**0.965**	0.809	-0.763	0.841	-0.718	0.852
Crispness	**0.995**	0.950	**0.951**	-0.896	**1**	**0.999**	**0.995**	**0.996**	**-0.964**	**-0.975**	**0.957**	**-0.983**	0.932	**-0.989**
Hardness	**0.996**	**0.956**	**0.958**	-0.873	**0.999**	**1**	**0.999**	**0.999**	**-0.952**	**-0.981**	**0.965**	**-0.986**	0.943	**-0.991**
Crunchiness	**0.993**	**0.954**	**0.957**	-0.851	**0.995**	**0.999**	**1**	**0.999**	-0.937	**-0.987**	**0.975**	**-0.989**	**0.956**	**-0.993**
Juiciness	**0.997**	**0.964**	**0.966**	-0.858	**0.996**	**0.999**	**0.999**	**1**	-0.946	**-0.980**	**0.965**	**-0.983**	0.944	**-0.988**
Mealiness	**-0.964**	-0.925	-0.923	**0.965**	**-0.964**	**-0.952**	-0.937	-0.946	**1**	0.885	-0.847	0.905	-0.804	0.918
TSS	**-0.961**	-0.900	-0.905	0.809	**-0.975**	**-0.981**	**-0.987**	**-0.980**	0.885	**1**	**-0.997**	**0.998**	**-0.989**	**0.997**
TA	0.942	0.880	0.886	-0.763	**0.957**	**0.965**	**0.975**	**0.965**	-0.847	**-0.997**	**1**	**-0.991**	**0.997**	**-0.988**
TSS/TA	**-0.967**	-0.900	-0.905	0.841	**-0.983**	**-0.986**	**-0.989**	**-0.983**	0.905	**0.998**	**-0.991**	**1**	**-0.980**	**0.999**
Firmness	0.915	0.850	0.857	-0.718	0.932	0.943	**0.956**	0.944	-0.804	**-0.989**	**0.997**	**-0.980**	**1**	**-0.974**
DMC	**-0.975**	-0.912	-0.916	0.852	**-0.989**	**-0.991**	**-0.993**	**-0.988**	0.918	**0.997**	**-0.988**	**0.999**	**-0.974**	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table 8 Attributes of the consumers expressed as percentage of the 2013 total consumer group (n=450) for black, coloured and white consumers.

Consumer attributes	Black	Coloured	White	Total
Age				
Young (18-25)	14	18	35	67
Older (26+)	9	16	8	33
Gender				
Male	10	12	15	37
Female	13	22	28	63
Consumption of apples				
Frequent (≤ 2-3x week)	14	20	30	64
Less frequent (≤ 1x month)	9	14	13	36
Total consumer group (%)	23	34	43	100

Table 9 Attributes of the consumers expressed as percentage of the 2014 total consumer group (n=240) for black, coloured and white consumers.

Consumer attributes	Black	Coloured	White	Total
Age				
Young (18-25)	9	13	40	62
Older (26+)	8	20	10	38
Gender				
Male	6	16	14	36
Female	11	17	36	64
Consumption of apples				
Frequent (≤ 2-3x week)	13	19	27	59
Less frequent (≤ 1x month)	4	14	23	41
Ideal apple texture				
Hard and very crisp	12	18	42	72
Slightly soft and ripe	4	13	7	24
Soft and slightly mealy	1	2	1	4
Total consumer group (%)	17	33	50	100

Table 10 ANOVA table with main and interaction effects for ethnic group, gender and age with actual preference for texture, taste and appearance of 'Golden Delicious' in 2013 and 2014, respectively of varying shelf-life duration.

Factor	DF	Pr > F		
		Texture	Taste	Appearance
2013 Golden Delicious				
Ethnic group	2	**<0.0001**	**<0.0001**	**<0.0001**
Gender	1	0.3428	**0.0002**	0.6113
Ethnic group*Gender	2	0.348	0.654	0.0787
Age	1	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Age	2	**<0.0001**	**<0.0001**	**<0.0001**
Gender*Age	1	0.1532	**0.0232**	0.9732
Ethnic group*Gender*Age	2	**0.001**	0.643	**0.0016**
Ethnic group*Gender*Age(Consumer)	438	**<0.0001**	**<0.0001**	**<0.0001**
Day	4	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Day	8	0.0534	0.8284	**<0.0001**
Gender*Day	4	0.1099	0.0756	**0.0388**
Ethnic group*Gender*Day	8	0.8693	0.8329	0.5589
Age*Day	4	0.143	0.4022	**<0.0001**
Ethnic group*Age*Day	8	0.4723	0.247	**<0.0001**
Gender*Age*Day	4	0.6436	0.8121	0.4739
Ethnic group*Gender*Age*Day	8	0.2694	0.4982	0.7677
2014 Golden Delicious				
Ethnic group	2	<0.0001	<0.0001	**<0.0001**
Gender	1	<0.0001	**<0.0001**	**0.0026**
Ethnic group*Gender	2	<0.0001	**0.0024**	**0.0043**
Age	1	0.0002	0.7298	**0.0085**
Ethnic group*Age	2	<0.0001	**<0.0001**	**0.0006**
Gender*Age	1	0.0361	0.2588	0.1025
Ethnic group*Gender*Age	2	0.1291	0.0596	0.2742
Ethnic group*Gender*Age (Consumer)	228	**<0.0001**	**<0.0001**	**<0.0001**
Day	3	**<0.0001**	**0.0013**	**<0.0001**
Ethnic group*Day	6	0.1587	0.1623	**<0.0001**
Gender*Day	3	0.1386	0.3727	0.6202
Ethnic group*Gender*Day	6	0.6341	0.661	**0.0241**
Age*Day	3	0.1378	0.7755	0.0642
Ethnic group*Age*Day	6	0.1529	0.1902	0.2119
Gender*Age*Day	3	0.1208	0.0629	0.6477
Ethnic group*Gender*Age*Day	6	0.8083	0.7161	0.8578

Table 11 Mean preference scores for the texture and taste of 'Golden Delicious' in 2013 and 2014, respectively with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 7 days, 14 days, 21 days and 28 days old fruit respectively (2013) and 0 day, 9 days, 18 days and 27 days old fruit, respectively (2014). Means with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

Shelf-life duration	**Texture**	**Taste**
2013		
Day 0	5.8 a	6.0 b
Day 7	5.9 a	6.2 a
Day 14	5.6 b	5.9 bc
Day 21	5.4 b	5.8 c
Day 28	5.1 c	5.6 d
P-value	***<0.0001***	***<0.0001***
2014		
Day 0	5.6 a	6.1 a
Day 9	5.7 a	6.1 a
Day 18	5.5 a	6.3 a
Day 27	5.1 b	5.8 b
P-value	***<0.0001***	***0.0013***

Table 12 ANOVA table with main and interaction effects for ethnic group, gender and age with actual preference for texture, taste and appearance of 'Topred' in 2013 and 2014, respectively of varying shelf-life duration.

Factor	DF	Pr > F		
		Texture	Taste	Appearance
2013 Topred				
Ethnic group	2	0.2597	**<0.0001**	**0.0086**
Gender	1	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Gender	2	**0.0032**	0.0668	**0.0027**
Age	1	**0.0006**	**<0.0001**	**<0.0001**
Ethnic group*Age	2	**<0.0001**	**<0.0001**	**<0.0001**
Gender*Age	1	**<0.0001**	**0.0046**	**<0.0001**
Ethnic group*Gender*Age	2	0.8588	**0.0328**	0.5241
Ethnic group*Gender*Age (Consumer)	438	**<0.0001**	**<0.0001**	**<0.0001**
Day	4	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Day	8	**0.0007**	**0.0416**	0.2719
Gender*Day	4	0.2238	0.8246	**0.0166**
Ethnic group*Gender*Day	8	**0.0497**	0.7157	0.2512
Age*Day	4	0.1675	0.3012	**0.013**
Ethnic group*Age*Day	8	**0.0427**	0.2108	0.5569
Gender*Age*Day	4	0.8147	0.3918	0.195
Ethnic group*Gender*Age*Day	8	0.923	0.8913	0.4546
2014 Topred				
Ethnic group	2	**<0.0001**	**<0.0001**	**0.0002**
Gender	1	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Gender	2	**0.0007**	**0.0005**	**0.0058**
Age	1	0.0606	0.5534	**<0.0001**
Ethnic group*Age	2	**0.0004**	**<0.0001**	**0.001**
Gender*Age	1	0.2861	0.8111	**0.0334**
Ethnic group*Gender*Age	2	0.77	0.685	**0.0052**
Ethnic group*Gender*Age (Consumer)	228	**<0.0001**	**<0.0001**	**<0.0001**
Day	3	**<0.0001**	**<0.0001**	**<0.0001**
Ethnic group*Day	6	**0.035**	**0.0492**	**0.0007**
Gender*Day	3	0.3331	0.298	0.4001
Ethnic group*Gender*Day	6	0.6856	0.7014	0.8295
Age*Day	3	0.8647	0.6177	0.2034
Ethnic group*Age*Day	6	0.3751	**0.0304**	0.7007
Gender*Age*Day	3	0.7289	**0.0094**	0.1494
Ethnic group*Gender*Age*Day	6	0.678	0.4349	0.4138

Table 13 ANOVA table with main and interaction effects for ethnic group, gender and age with conceptual preference of sensory attributes.

Factor	2013		2014	
	DF	Pr > F	DF	Pr > F
Ethnic group	2	**<0.0001**	2	0.5593
Gender	1	**<0.0001**	1	0.3312
Ethnic group*Gender	2	0.7706	2	0.7079
Age	1	**0.0019**	1	0.7961
Ethnic group*Age	2	**<0.0001**	2	0.384
Gender*Age	1	**0.0352**	1	0.0677
Ethnic group*Gender*Age	2	0.1358	2	0.6895
Ethnic group*Gender*Age (Consumer)	438	**<0.0001**	228	**<0.0001**
Sensory attributes	12	**<0.0001**	8	**<0.0001**
Ethnic group*Sensory attributes	24	**<0.0001**	16	**<0.0001**
Gender*Sensory attributes	12	0.1754	8	0.2055
Ethnic group*Gender*Sensory attributes	24	0.1537	16	0.1134
Age*Sensory attributes	12	**0.0006**	8	0.069
Ethnic group*Age*Sensory attributes	24	**<0.0001**	16	**0.0001**
Gender*Age*Sensory attributes	12	0.2421	8	0.6798
Ethnic group*Gender*Age*Sensory attributes	24	0.3062	16	0.5119

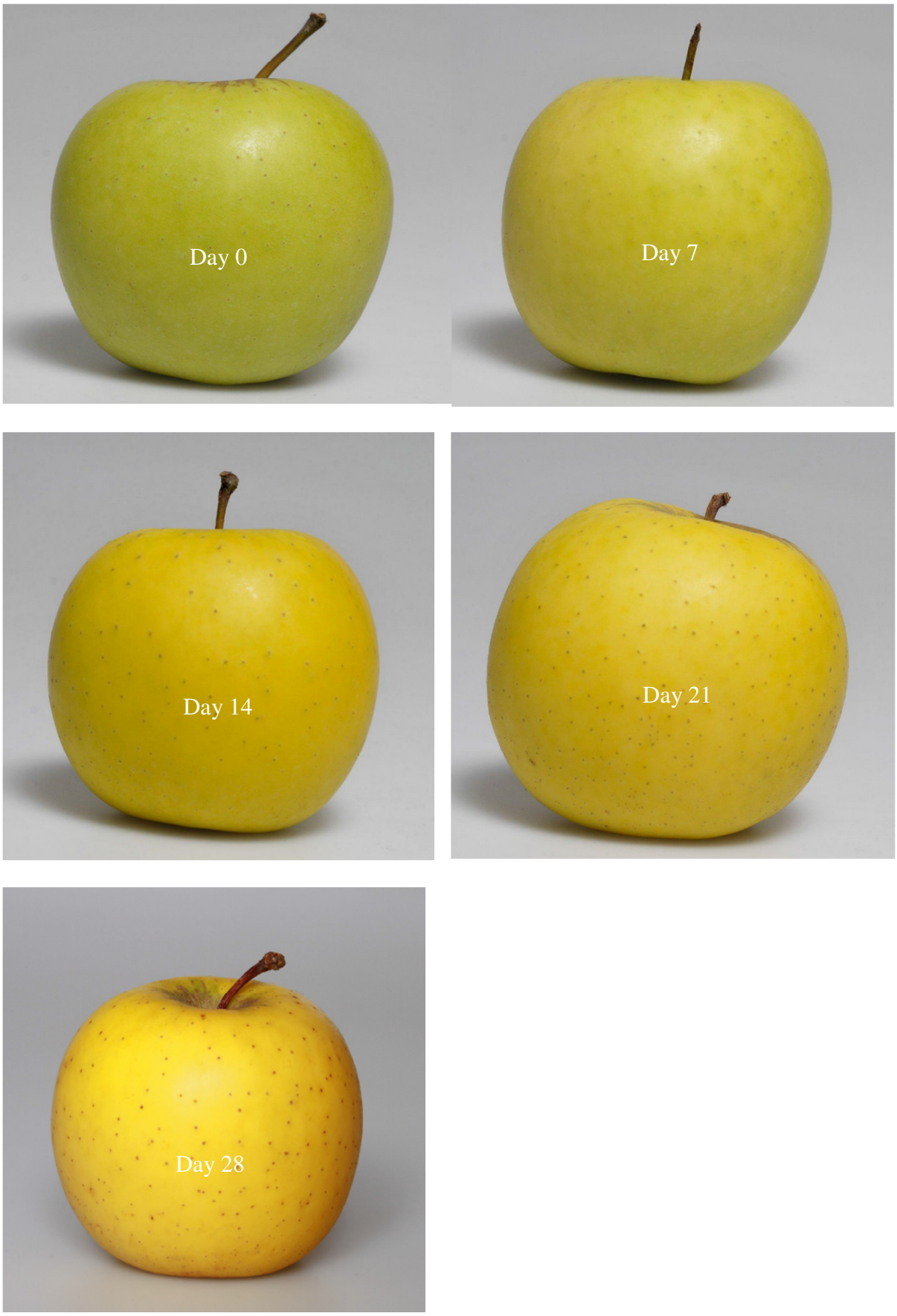

Figure 1 Photographs of all five 'Golden Delicious' treatments analysed in the 2013 eating quality test.

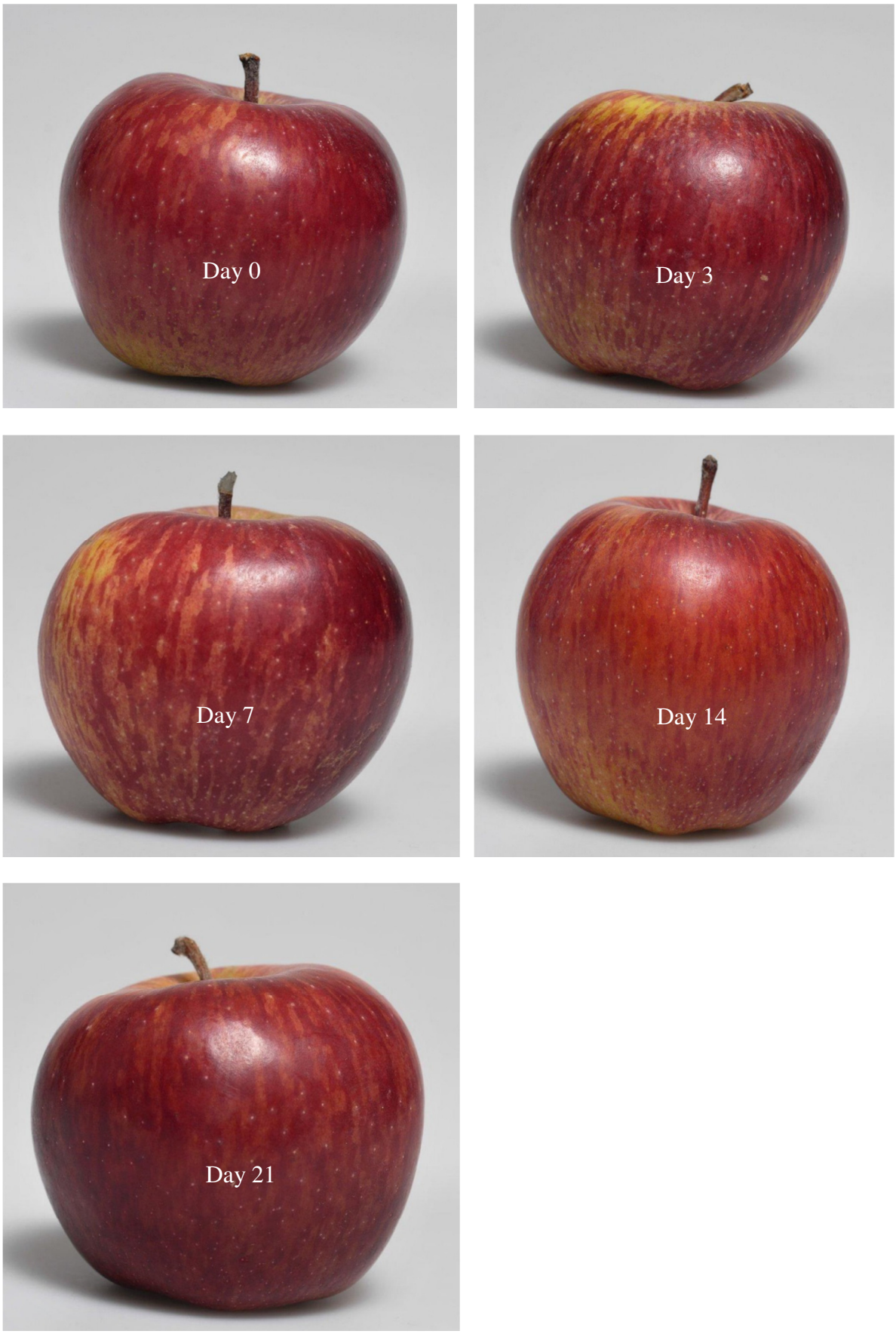

Figure 2 Photographs of all five 'Topred' treatments analysed in the 2013 eating quality test.

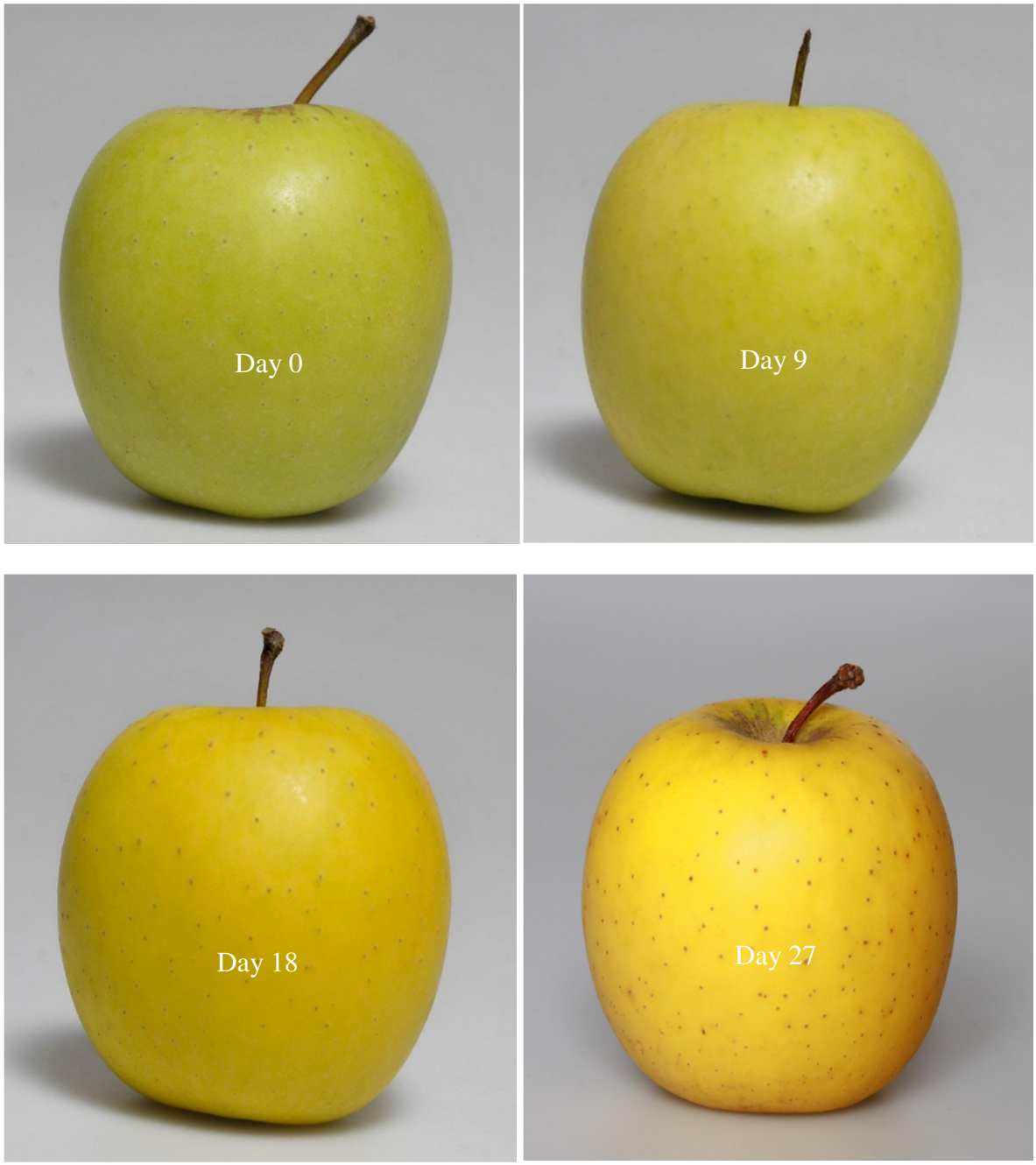

Figure 3 Photographs of all four 'Golden Delicious' treatments analysed in the 2014 eating quality test.

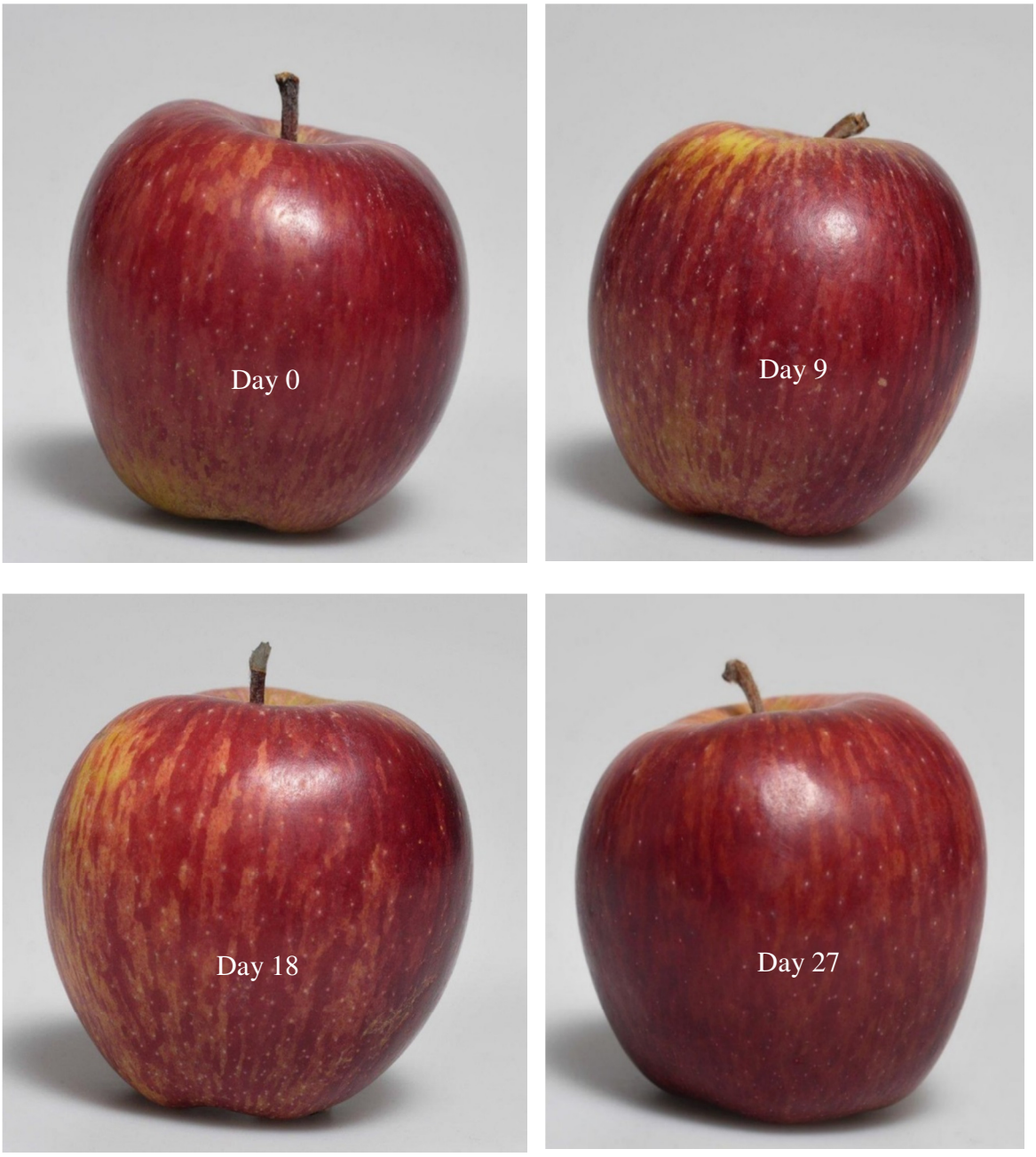

Figure 4 Photographs of all four 'Topred' treatments analysed in the 2014 eating quality test.

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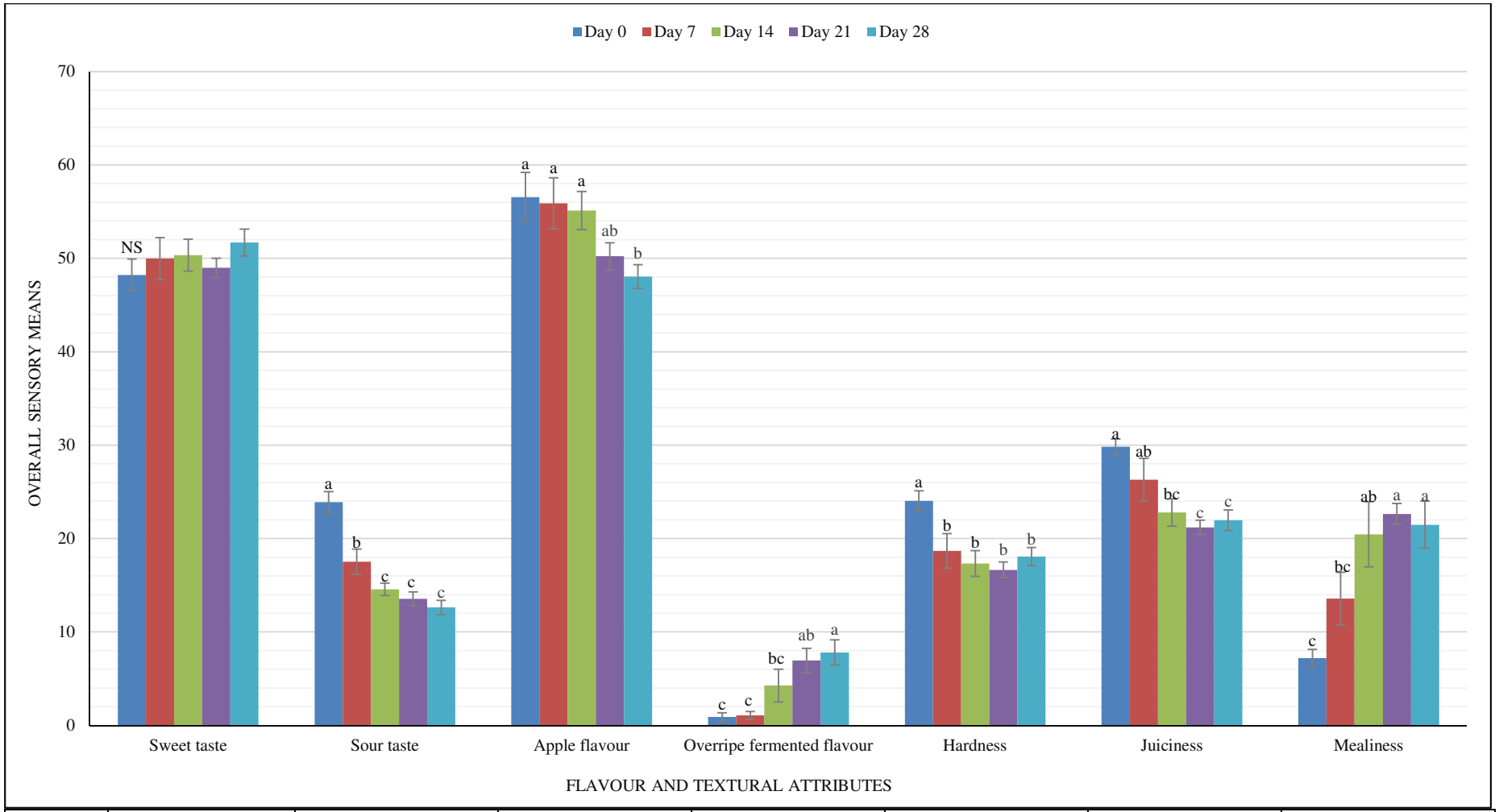
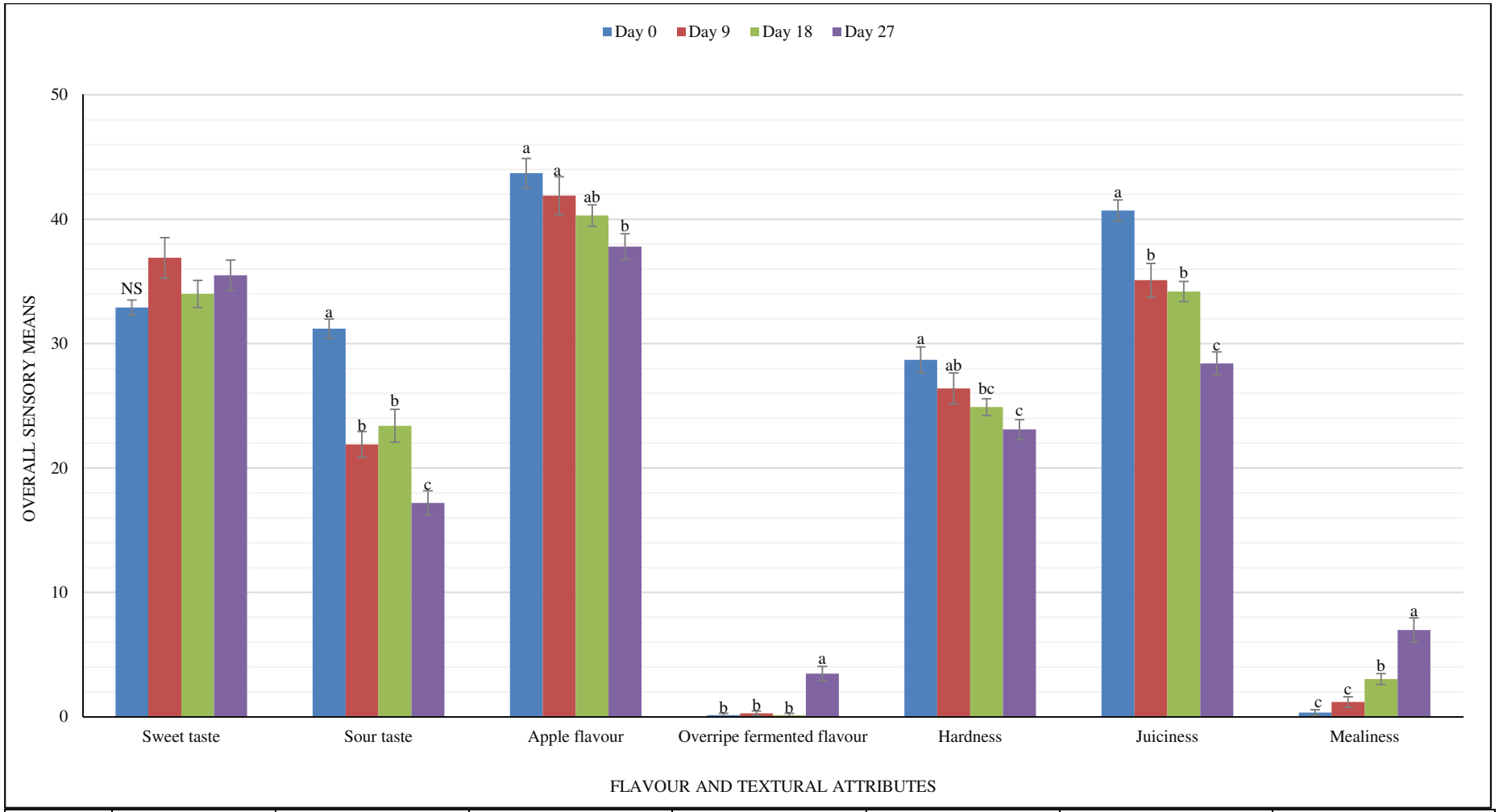


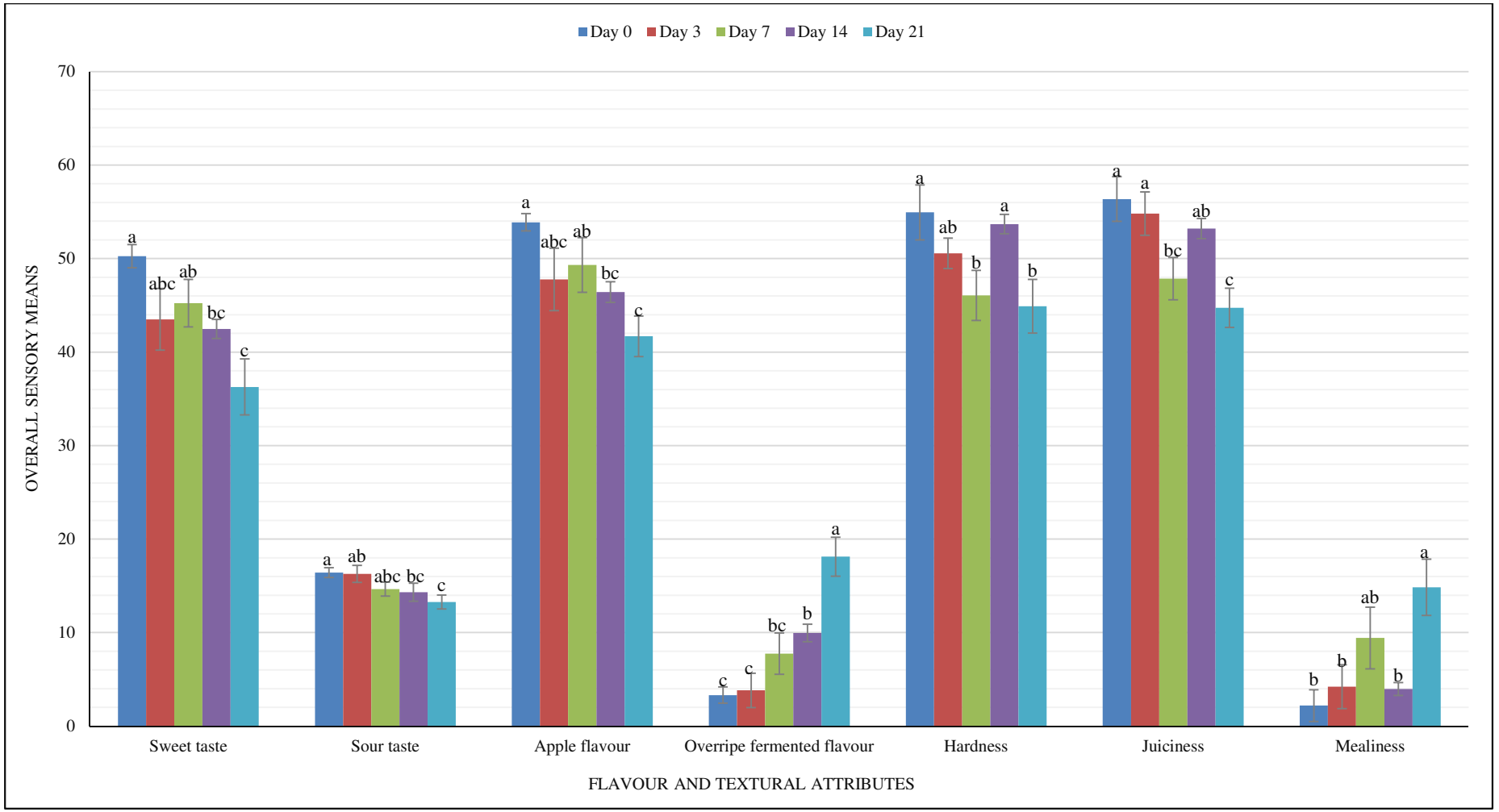
P-value	***0.7153***	***<0.0001***	***0.0388***	***0.0010***	***0.0070***	***0.0004***	***0.0008***

Figure 5 Overall means of sensory flavour and textural attributes measured on a 100 mm line scale during descriptive sensory analysis of 2013 'Golden Delicious' with varying shelf-life duration, i.e., 0 day, 7 days, 14 days, 21 days and 28 days old fruit respectively. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.



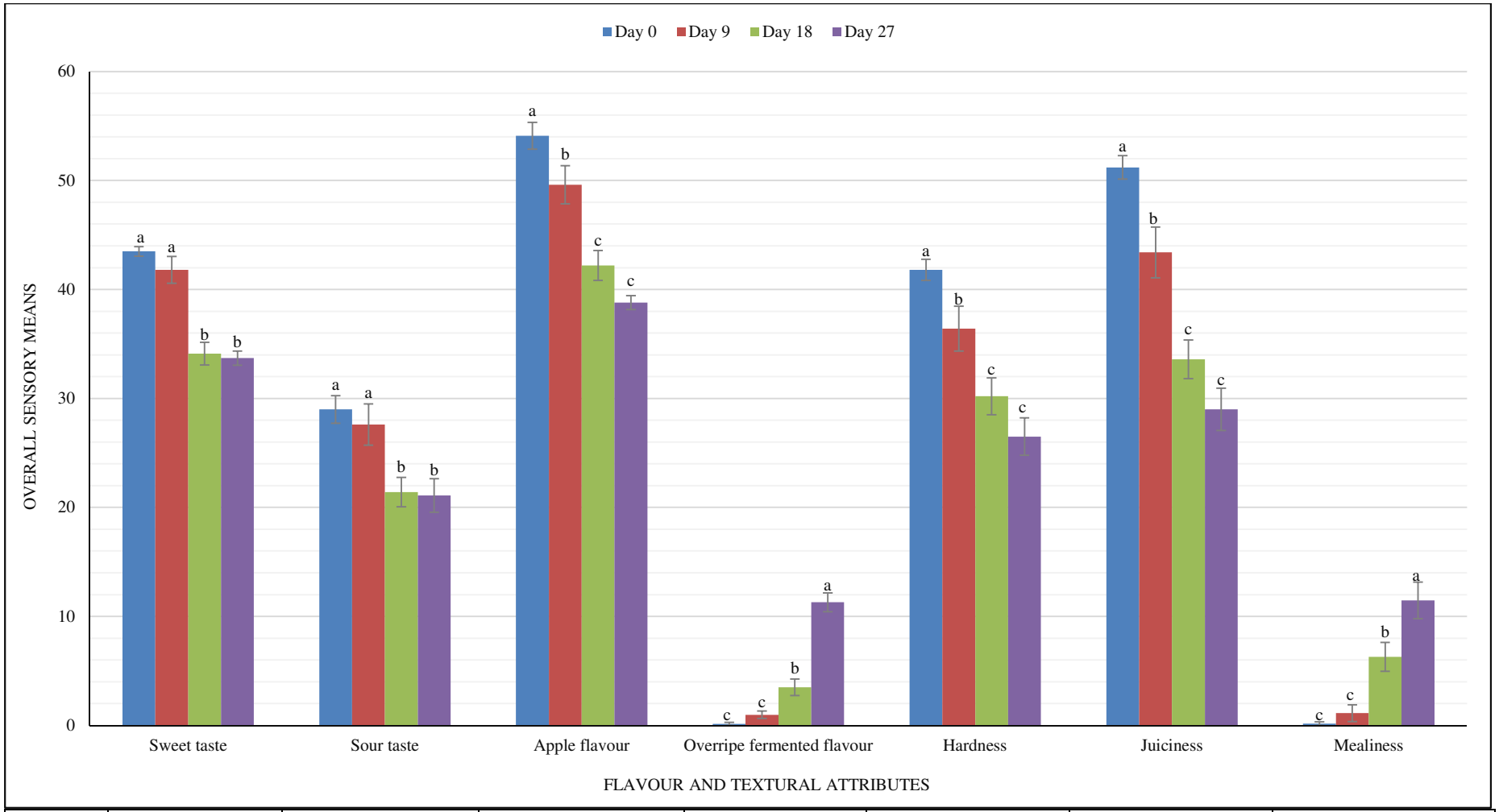
P-value	***0.1909***	***<0.0001***	***0.0257***	***<0.0001***	***0.0031***	***<0.0001***	***<0.0001***

Figure 6 Overall means of sensory flavour and textural attributes measured on a 100 mm line scale during descriptive sensory analysis of 2014 'Golden Delicious' with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit, respectively. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.



P-value	***0.0128***	***0.0178***	***0.0348***	***<0.0001***	***0.0403***	***0.0095***	***0.0165***

Figure 7 Overall means of sensory flavour and textural attributes measured on a 100 mm line scale during descriptive sensory analysis of 2013 'Topred' with varying shelf-life duration, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit, respectively. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.



P-value	***<0.0001***	***0.0020***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***

Figure 8 Overall means of sensory flavour and textural attributes measured on a 100 mm line scale during descriptive sensory analysis of 2014 'Topred' with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit, respectively. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

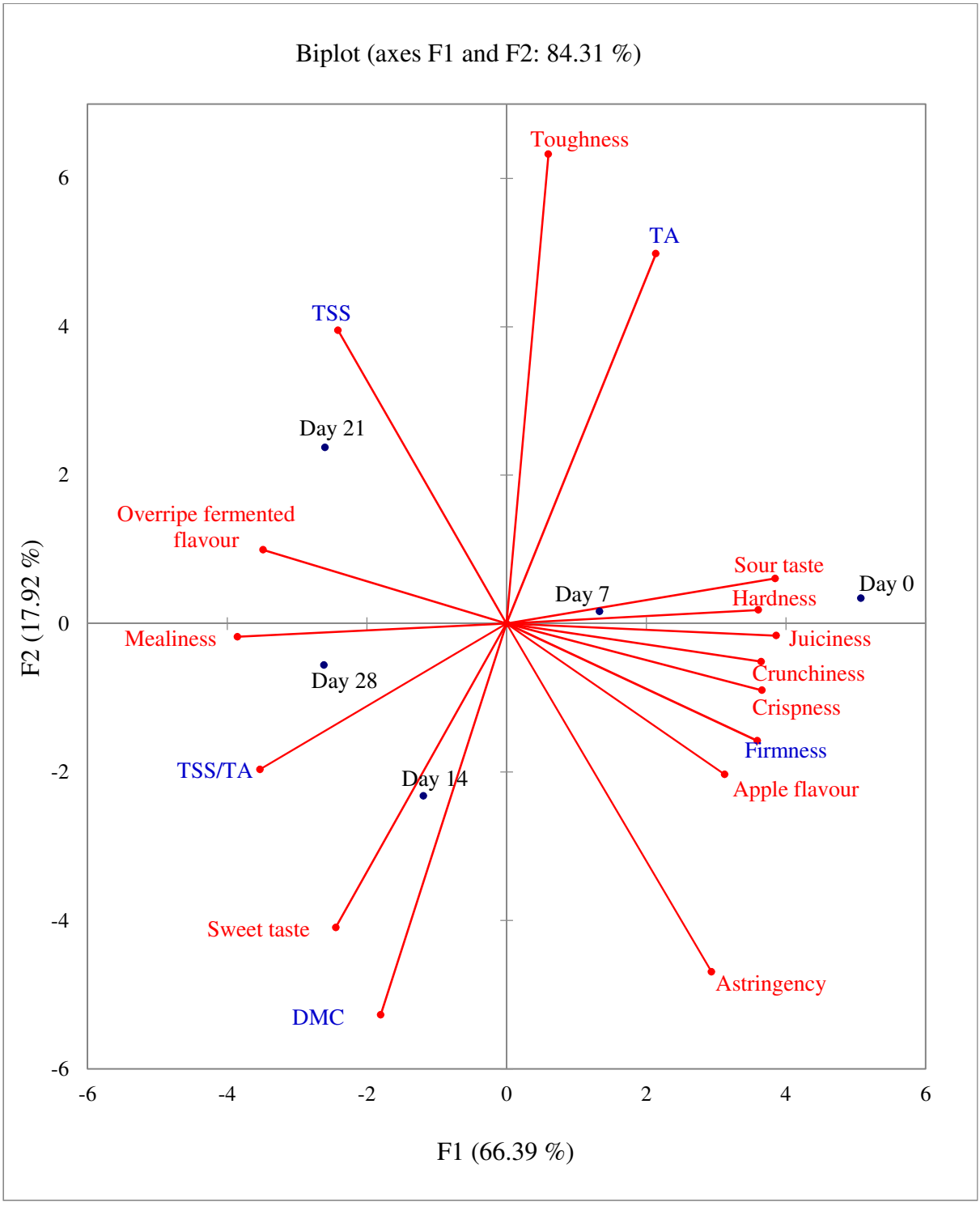


Figure 9 Principal component analysis bi-plot indicating the correlation between overall sensory attributes and instrumental measurements of 2013 'Golden Delicious' with varying shelf-life duration, i.e., 0 day, 7 days, 14 days, 21 days and 28 days old fruit, respectively.

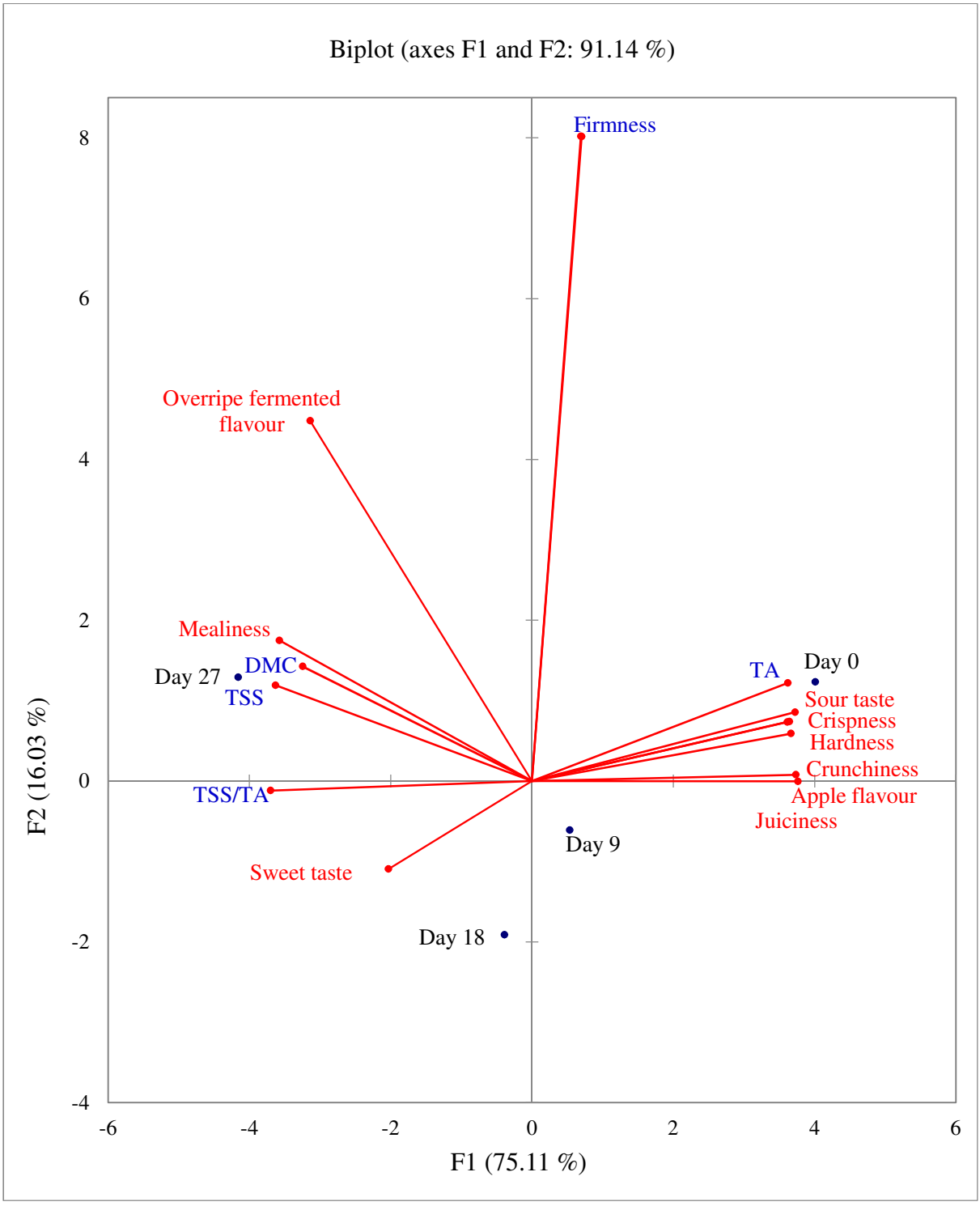


Figure 10 Principal component analysis bi-plot indicating the correlation between overall sensory attributes and instrumental measurements of 2014 'Golden Delicious' with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit, respectively.

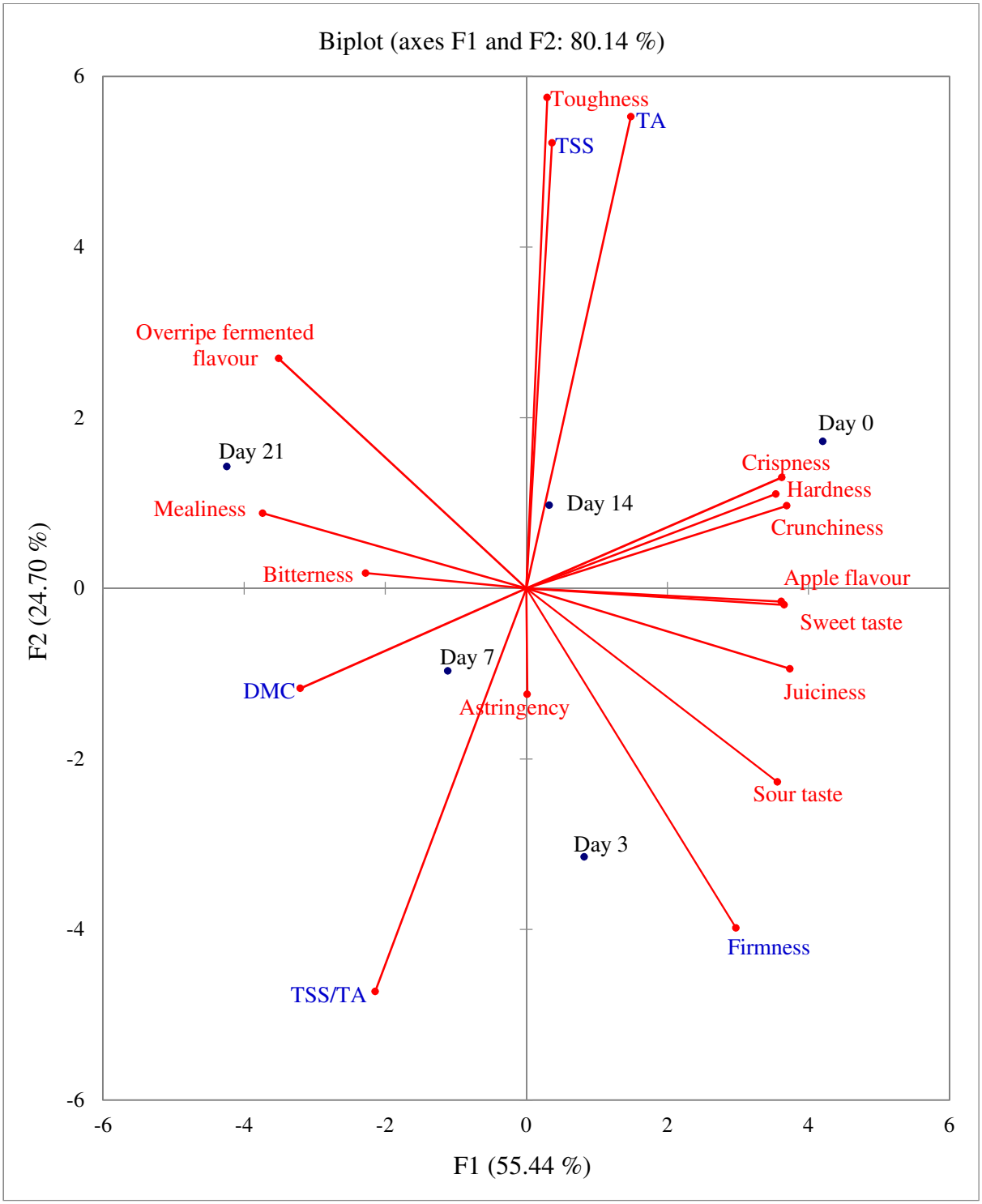


Figure 11 Principal component analysis bi-plot indicating the correlation between overall sensory attributes and instrumental measurements of 2013 'Topred' with varying shelf-life duration, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit, respectively.

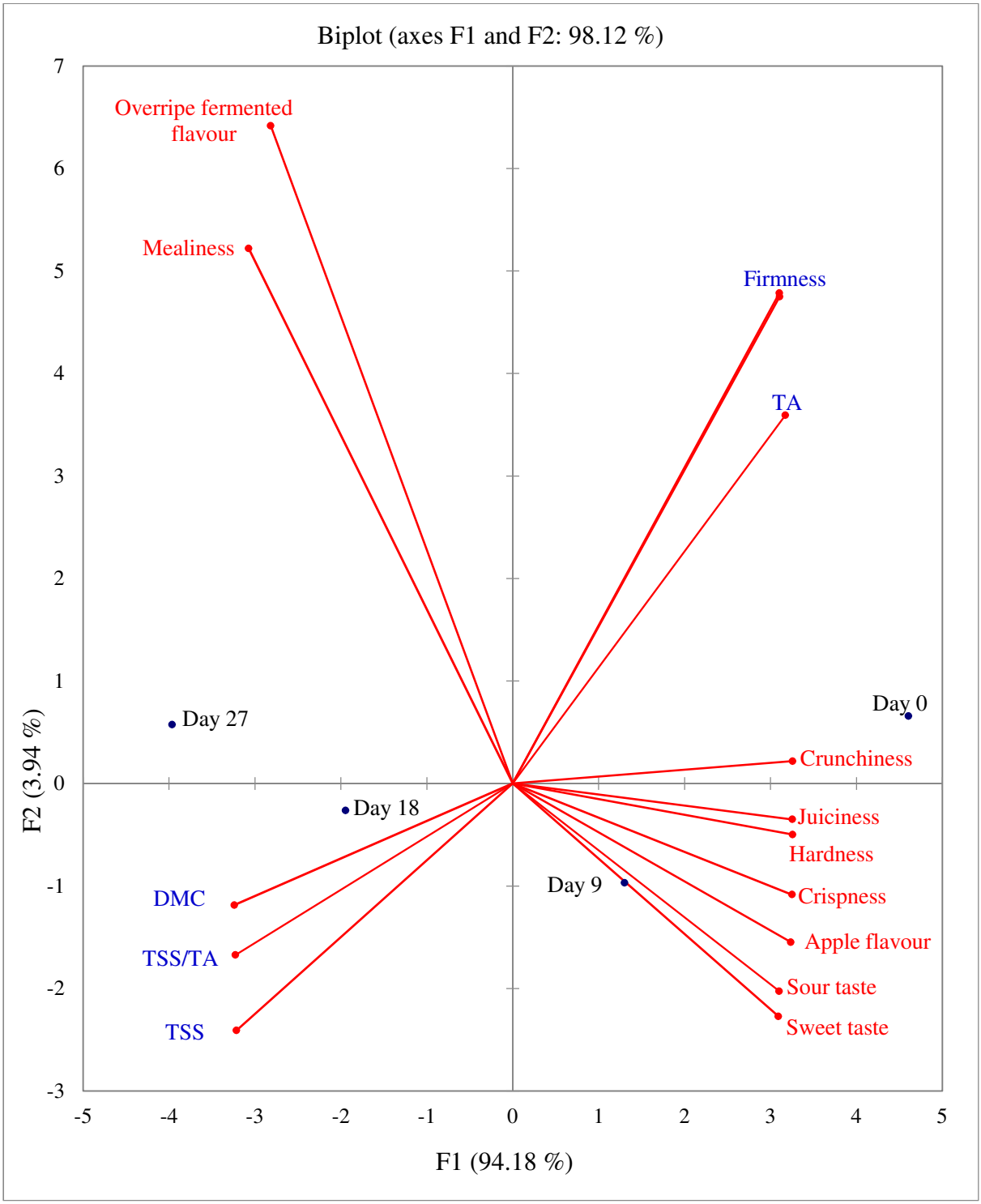


Figure 12 Principal component analysis bi-plot indicating the correlation between overall sensory attributes and instrumental measurements of 2014 'Topred' with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit, respectively.

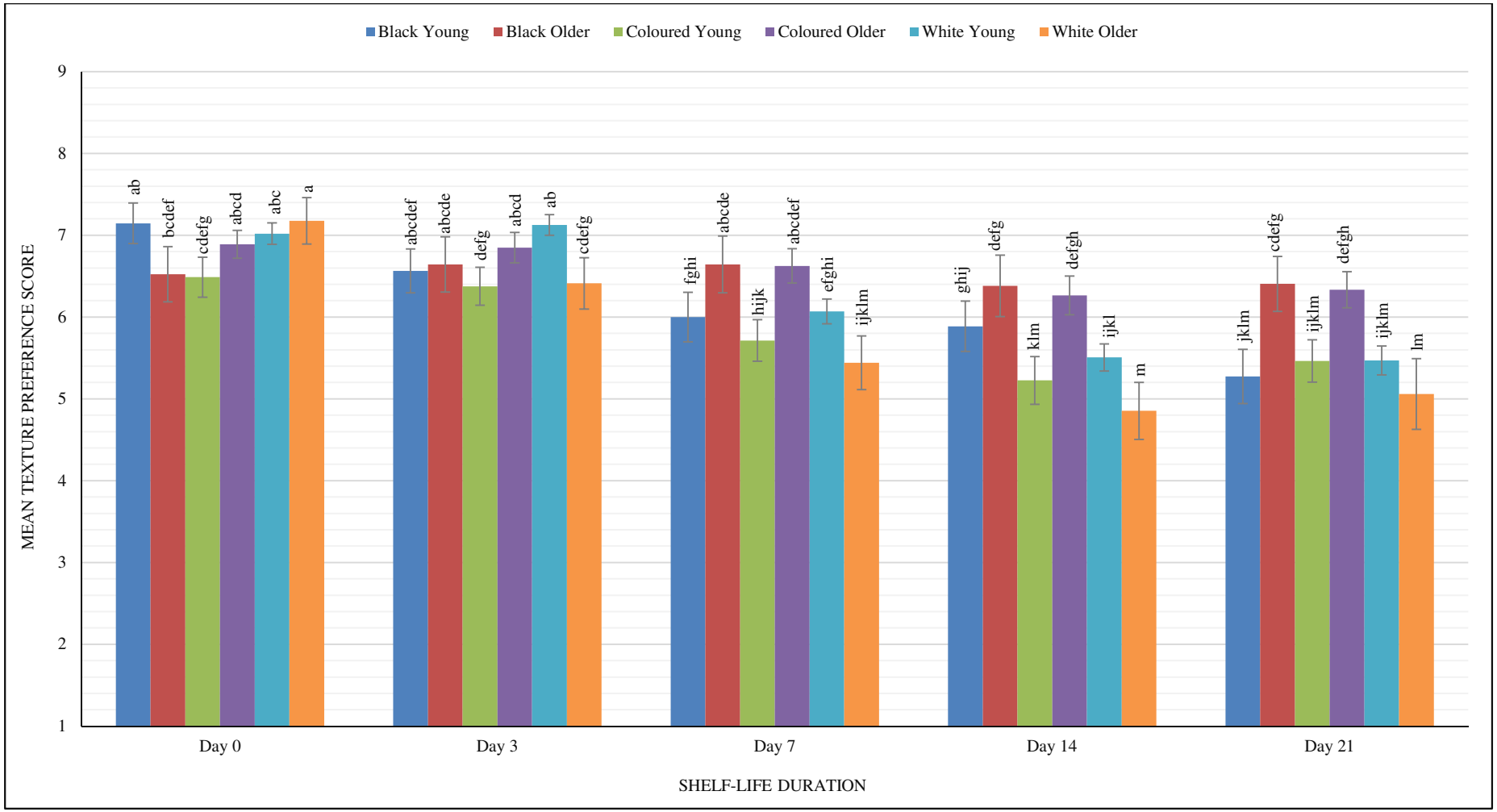


Figure 13 Mean preference scores for the overall texture quality of 2013 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit respectively for the different ethnic (black, coloured and white) and age groups (young and older). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

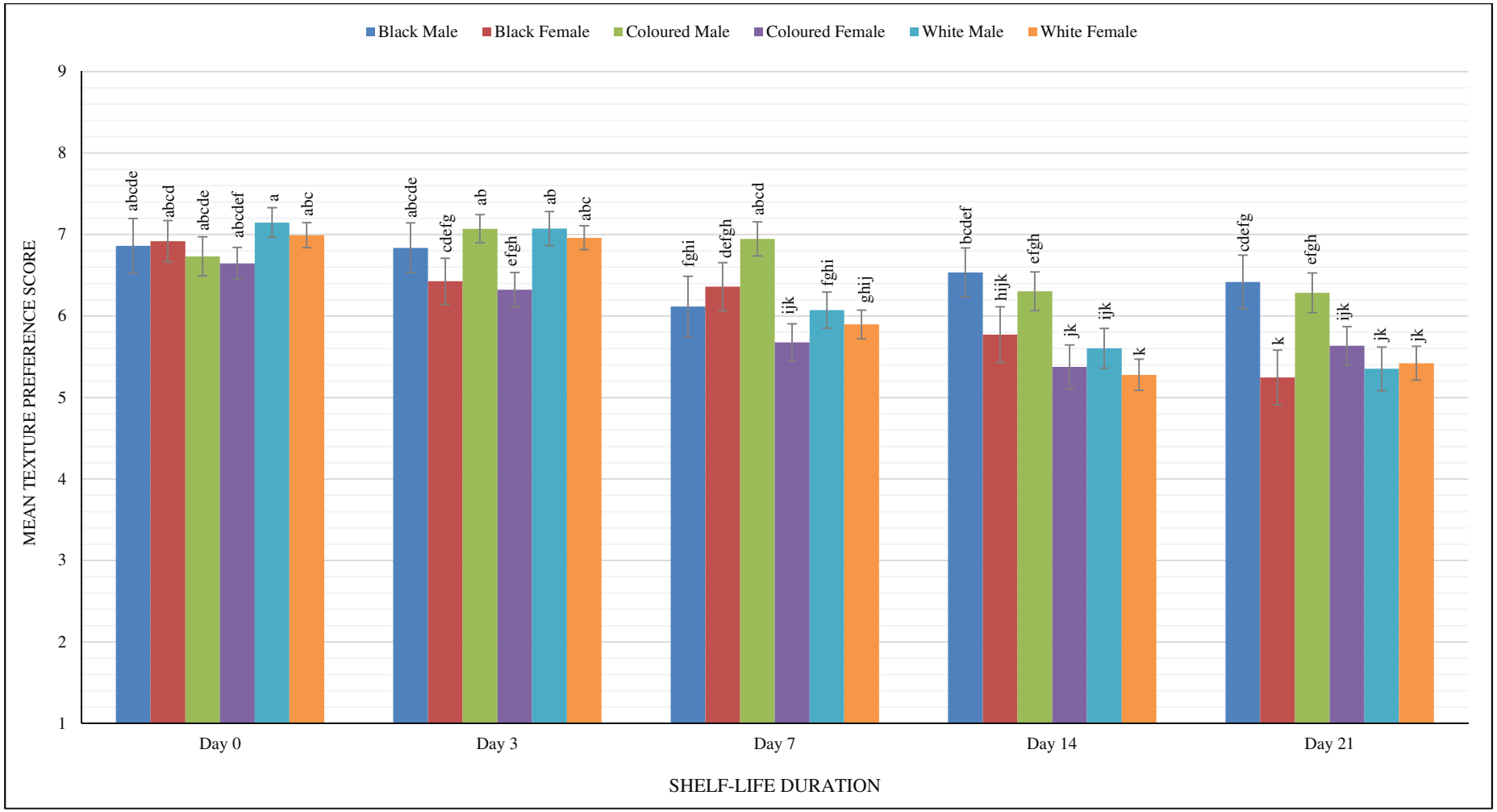


Figure 14 Mean preference scores for the overall texture quality of 2013 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit respectively for the different ethnic groups (black, coloured and white) and gender (male and female). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

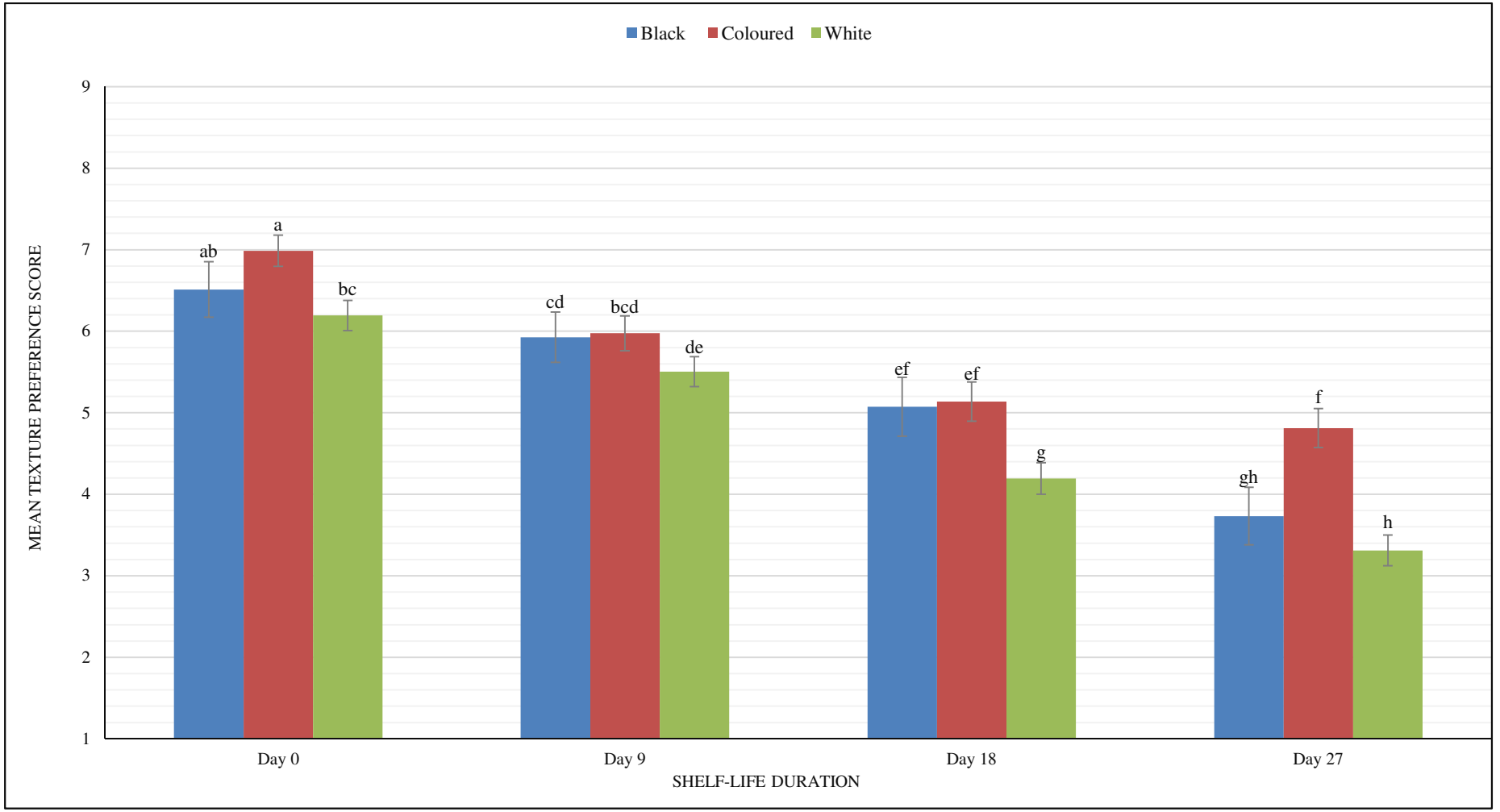


Figure 15 Mean preference scores for the overall texture quality of 2014 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 9 days, 18 days and 27 days old fruit respectively for different ethnic groups (black, coloured and white). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

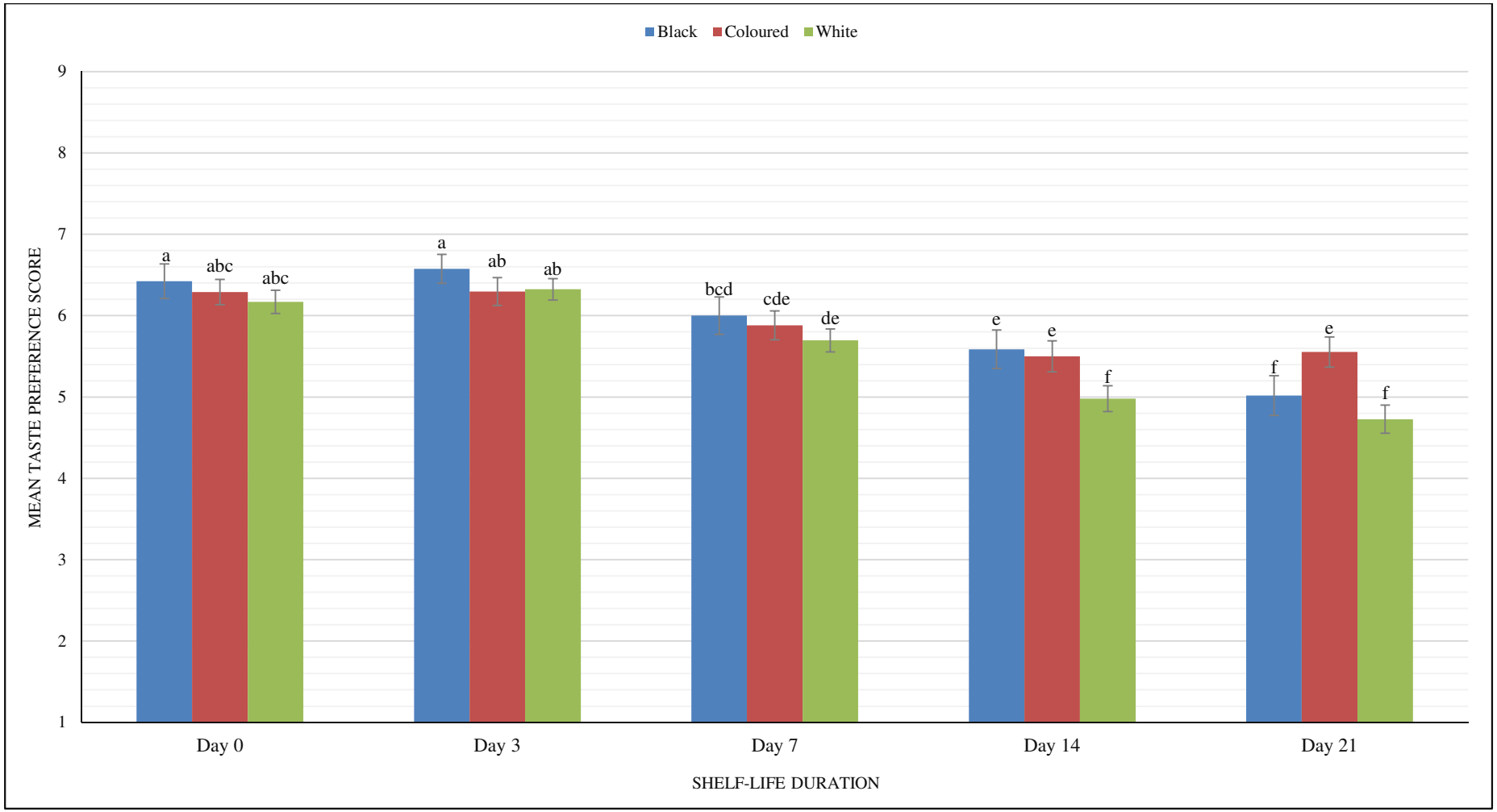


Figure 16 Mean preference scores for the overall taste quality of 2013 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit respectively for the different ethnic groups (black, coloured and white). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

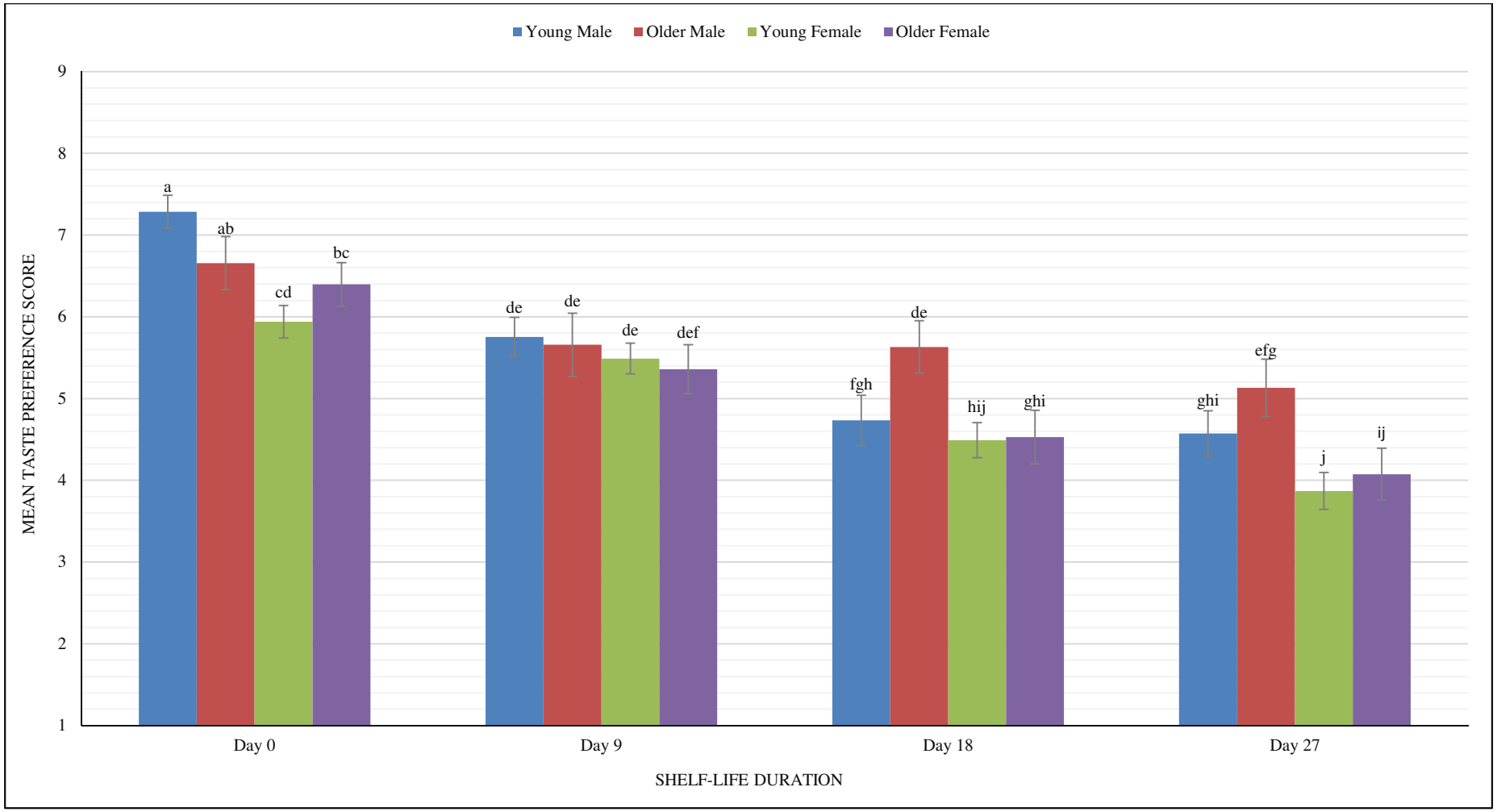


Figure 17 Mean preference scores for the overall taste quality of 2014 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 9 days, 18 days and 27 days old fruit respectively for gender (male and female) and different age groups (young and older). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

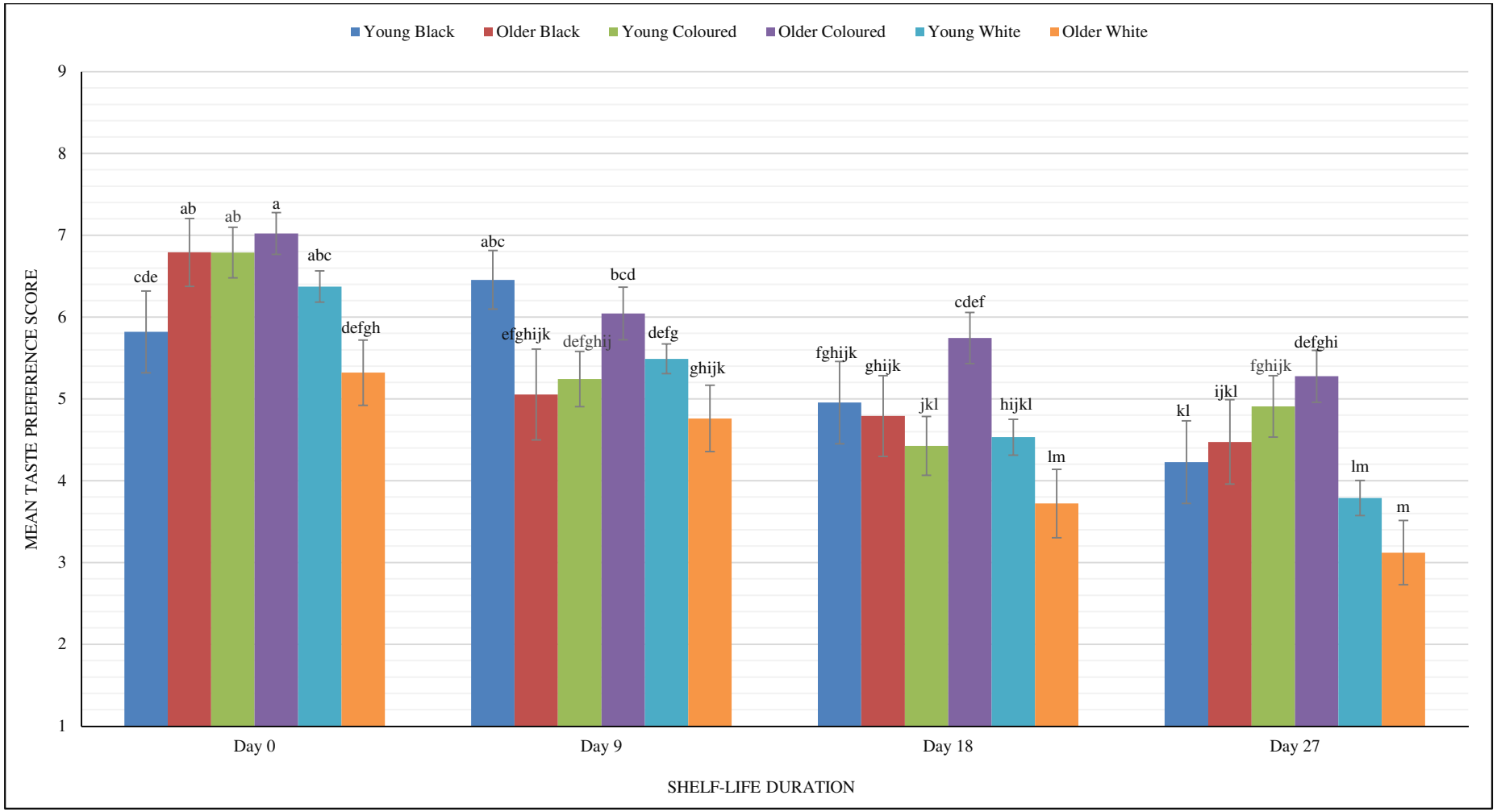


Figure 18 Mean preference scores for the overall taste quality of 2014 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration in the actual eating quality analysis, i.e., 0 day, 9 days, 18 days and 27 days old fruit respectively for ethnic (black, coloured and white) and age groups (young and older). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

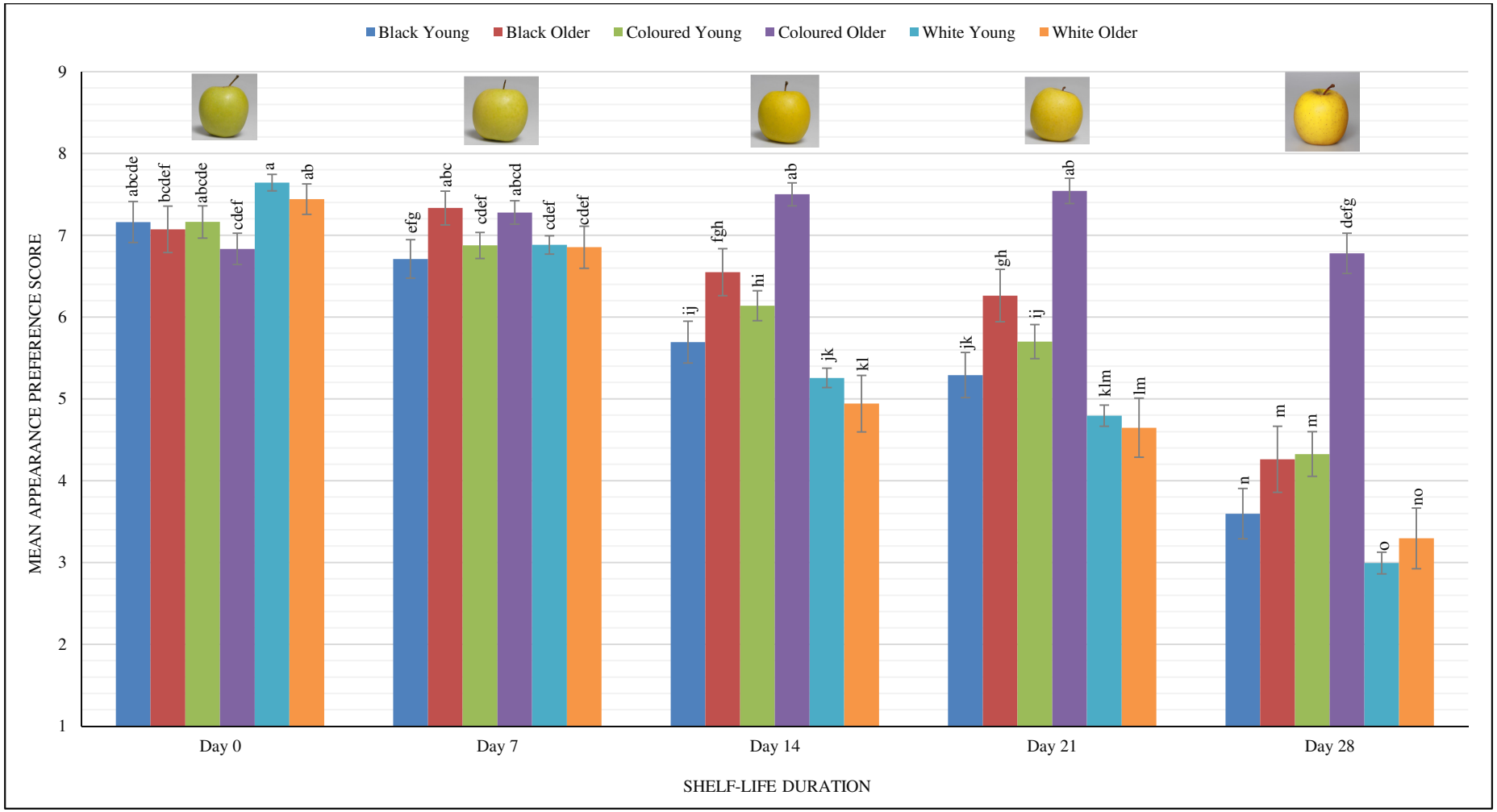


Figure 19 Mean appearance preference scores for 2013 Golden Delicious cultivar after 16 weeks cold storage at -0.5 °C of varying shelf-life duration, i.e., 0 day, 7 days, 14 days, 21 days and 28 days old fruit respectively for different ethnic (black, coloured and white) and age groups (young and older). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

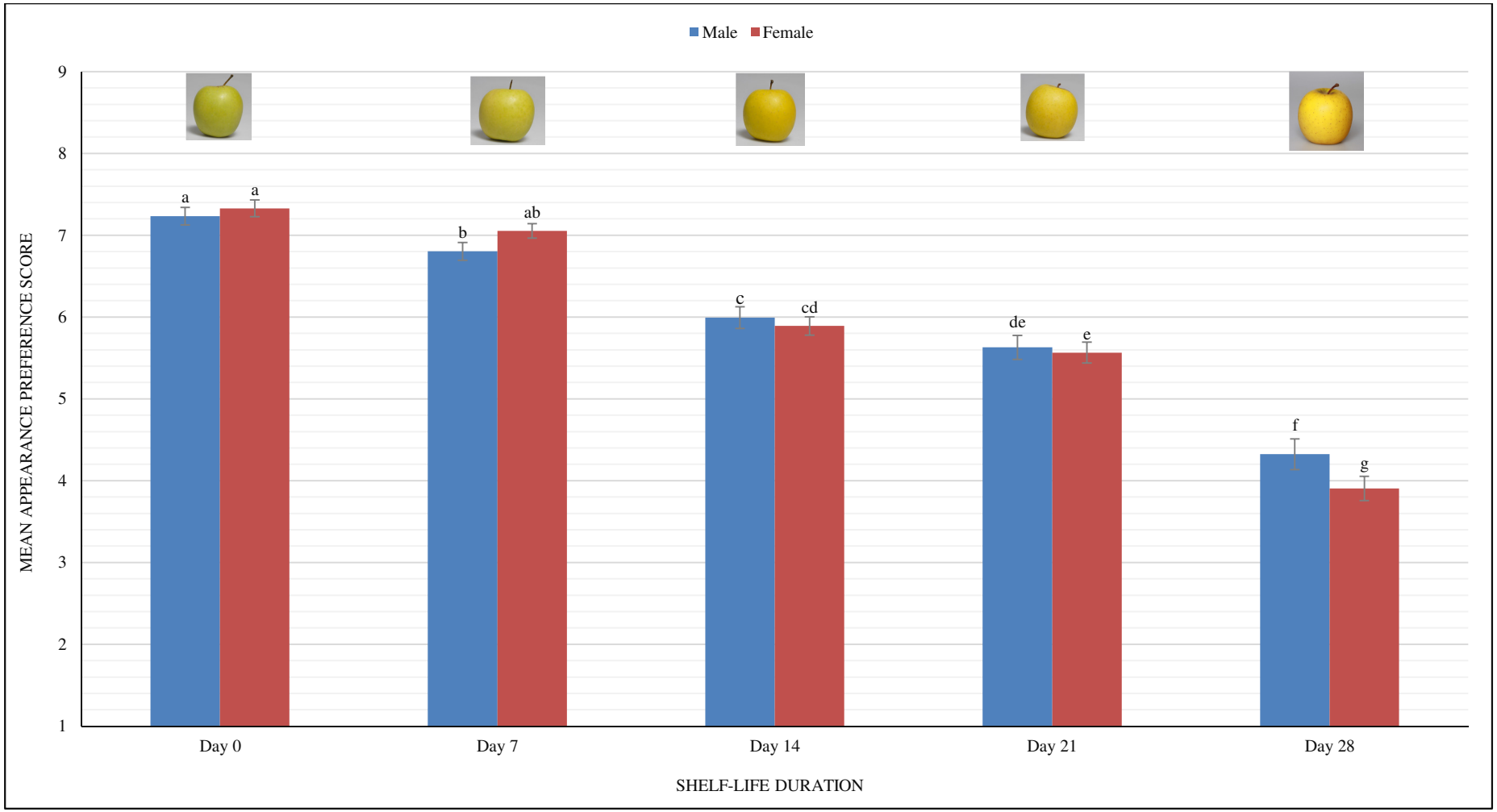


Figure 20 Mean appearance preference scores for 2013 Golden Delicious cultivar after 16 weeks cold storage at -0.5 °C with varying shelf-life duration, i.e., 0 day, 7 days, 14 days, 21 days and 28 days old fruit respectively for different gender (male and female). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

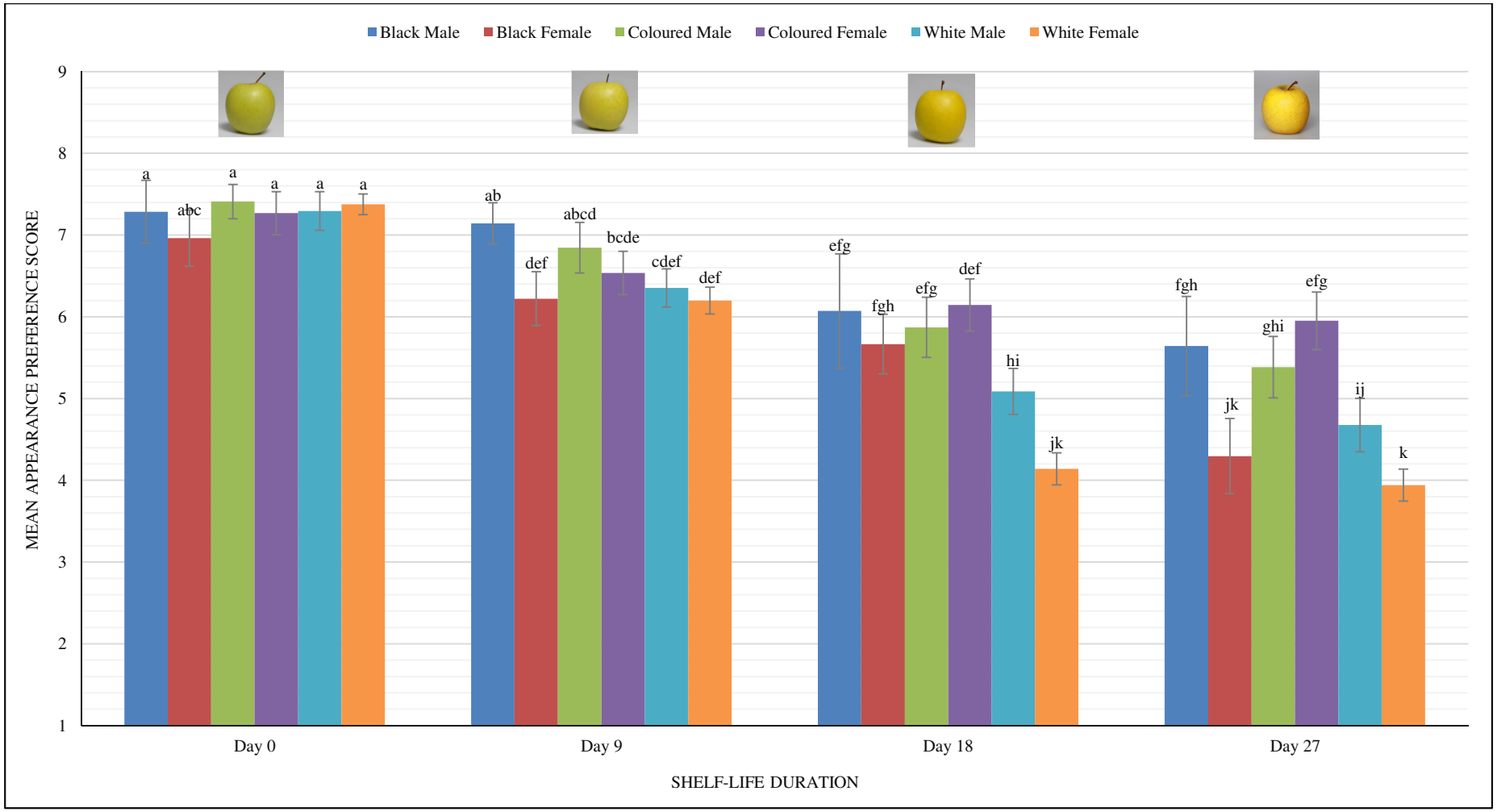


Figure 21 Mean appearance preference scores for 2014 Golden Delicious cultivar after 15 weeks cold storage at -0.5 °C with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit respectively for different ethnic groups (black, coloured and white) and gender (male and female). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

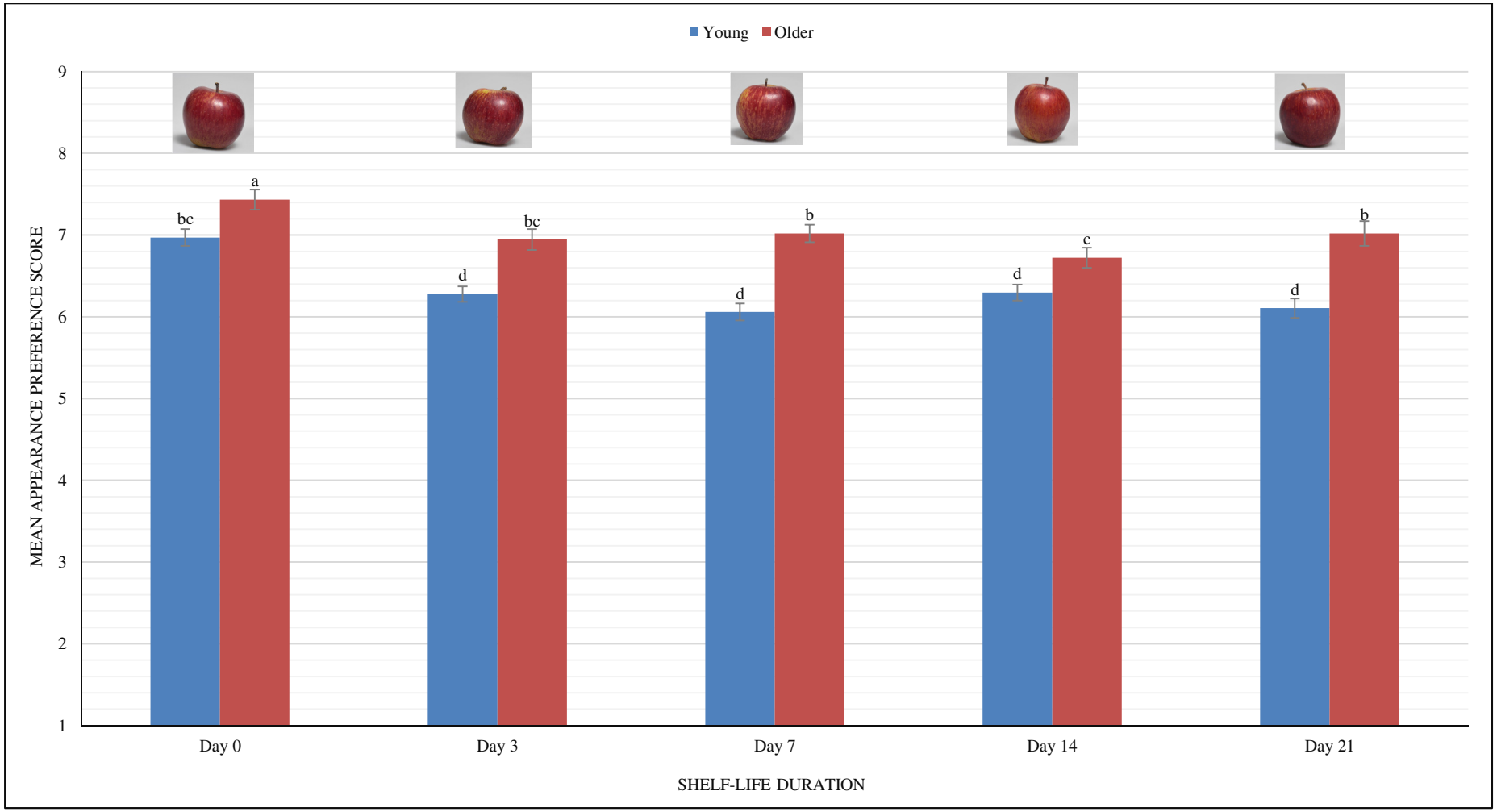


Figure 22 Mean appearance preference scores for 2013 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit respectively for different age groups (young and older). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

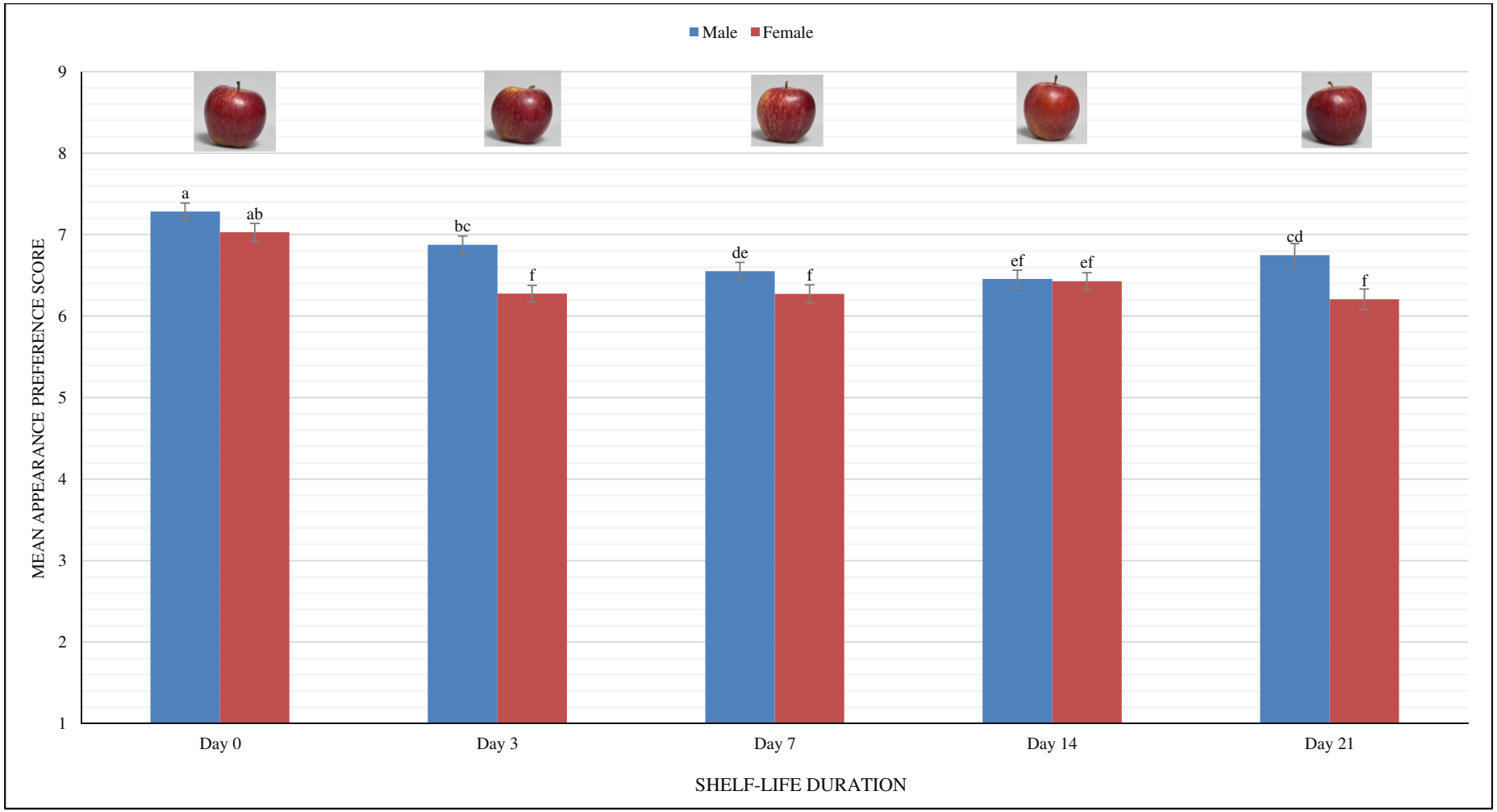


Figure 23 Mean appearance preference scores for 2013 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration, i.e., 0 day, 3 days, 7 days, 14 days and 21 days old fruit respectively for different gender (male and female). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

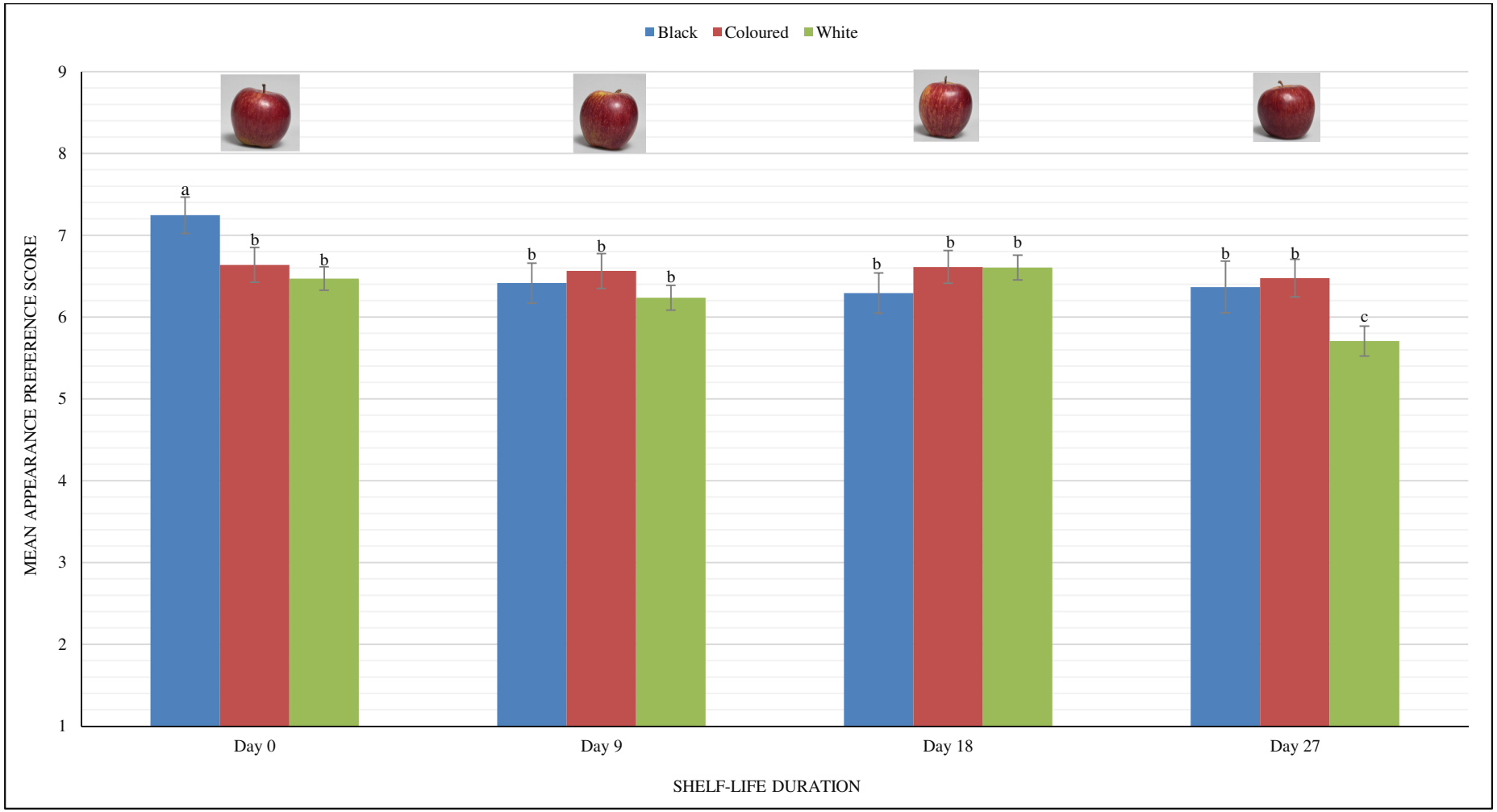


Figure 24 Mean appearance preference scores for 2014 Topred cultivar after 11 weeks cold storage at -0.5 °C with varying shelf-life duration, i.e., 0 day, 9 days, 18 days and 27 days old fruit respectively for the different ethnic groups (black, coloured and white). Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

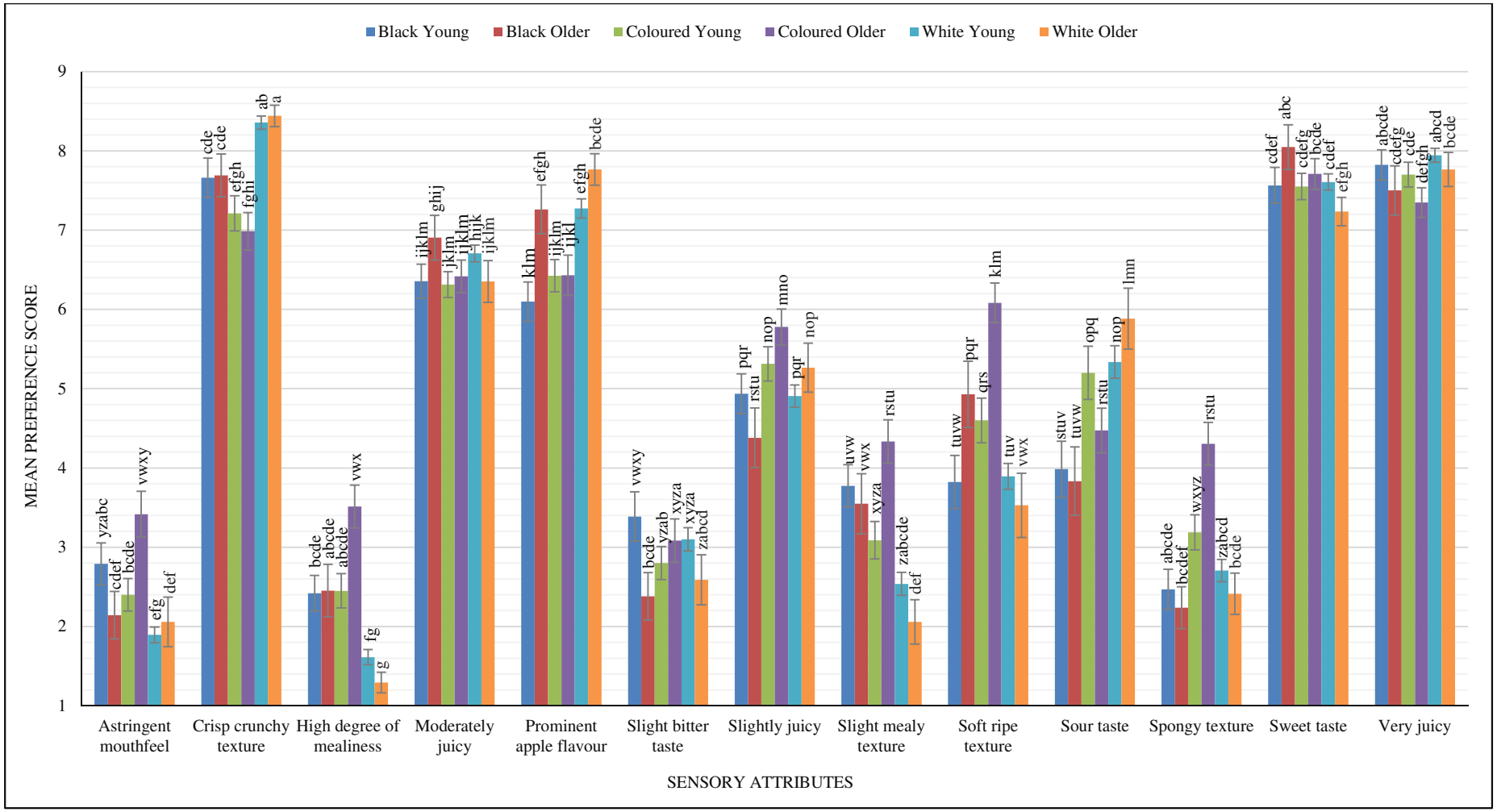


Figure 25 Mean preference scores for apple sensory attributes as evaluated conceptually by different ethnic (black, coloured and white) and age groups (young and older) in 2013 study. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

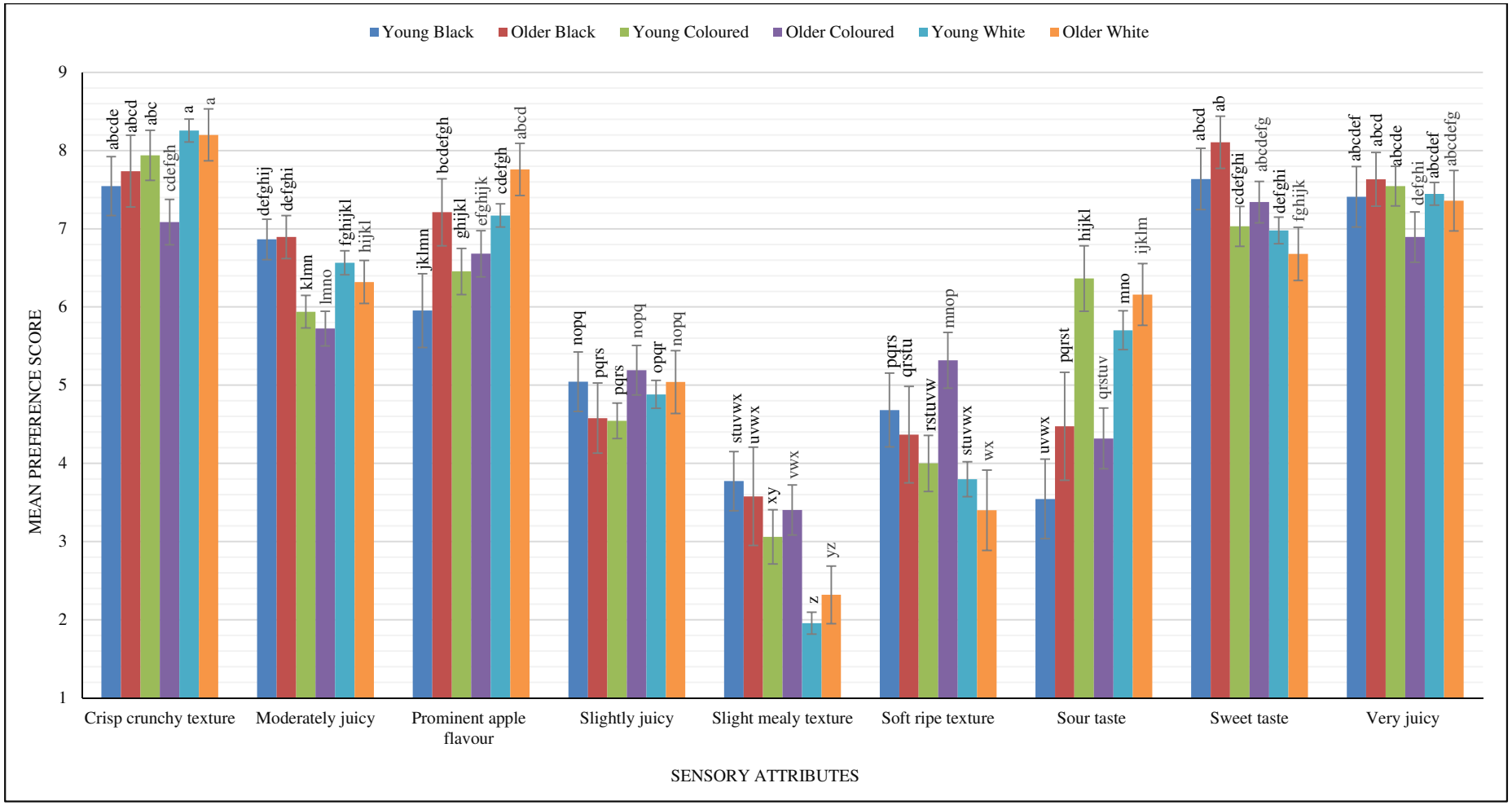


Figure 26 Mean preference scores for apple sensory attributes as evaluated conceptually by different ethnic (black, coloured and white) and age groups (young and older) in 2014 study. Means + standard errors with different alphabetical letters differ significantly. The least significant difference for each group is indicated at the 5% level of significance.

GENERAL DISCUSSION AND CONCLUSIONS

Determining the attributes that drive the preferences of South African consumers for apple eating quality and appearance is of prime importance. This is because 27% of South Africa's apple crop is sold on the local market (HORTGRO, 2015). A strong local market can buffer South African producers against global perturbations, such as the Russian embargo against European fruit imports (Rankin, 2014) and low international oil prices that pressurises sales in the African market (Naím, 2015) that may affect export sales. The per capita consumption of apples in South Africa is relatively low (4.5 kg) compared to for example China (23.1 kg), the European Union (15.0 kg) and New Zealand (14.2 kg) (HORTGRO, 2015). The local market is diverse with people of different ethnicities, viz. 80% black, 9% coloured, 8% white and 3% Indian/Asian (STATSSA, 2014) and socioeconomic levels still living in largely homogenous neighbourhoods, as legacy of a previous political dispensation, and favouring particular retailers that supply them with a certain offering of apple cultivars.

Due to the lack of empirical data on South African preferences for apple eating quality and appearance, we determined the attributes driving the preference of black and white consumers in Gauteng Province as well as black and Indian consumers in Kwa-Zulu Natal Province. Our study followed on earlier research conducted in collaboration between the Departments of Food Science and Horticultural Science among consumers of the Western Cape Province (Van der Merwe, 2013). We considered that the apple eating quality and appearance preferences of consumers in other provinces of South Africa may differ from preferences in the Western Cape Province where most apples are produced. The ethnic composition in the Western Cape, viz. 50% coloured, 30% black, 19% white and 1% Indian/Asian (STATSSA, 2014), differs considerably from other provinces in South Africa. The Gauteng Province consists of 74% black, 20% white, 4% coloured and 2% Indian/Asian consumers, while Kwa-Zulu Natal Province is made up of 85% black, 9% Indian/Asian, 5% white and 1% coloured consumers (STATSSA, 2014). We focused our study at these two provinces because, in addition to the Western Cape Province, Gauteng and Kwa-Zulu Natal are the provinces in South Africa with the highest spending power (STATSSA, 2015). These three provinces are the backbone of South Africa's economy and collectively contribute over 60% of the total Gross Domestic Product (GDP) (STATSSA, 2015). Also, the majority of

Indian/Asian consumers, whose preference pattern in relation to apple quality has not been documented, reside in the Kwa-Zulu Natal province (STATSSA, 2014).

We also determined whether the actual preferences as obtained in the consumer taste assessments were in agreement with the conceptual preferences of consumers. This would indicate to what extent consumers are aware of their preferences and also to what extent they are familiar with associations between appearance and eating quality expectations in apple. The factors influencing purchase decisions were investigated in order to obtain an understanding of the basis for possible differences in preferences. Using mean values for determining general preference tendencies of consumers, cluster analysis of mean centred preference data (Carbonell *et al*., 2008; Van der Merwe, 2013) was carried out to ascertain the preference patterns of specific consumer groups. We finally also evaluated how texture, taste and appearance differences of apple fruit with progressive maturity levels impact the eating quality and appearance preferences of Western Cape Province consumers of different ethnic and age groups. We used a full red and a yellow cultivar in this study, which allowed us to also determine the extent to which changes in peel colour during ripening provides consumers with information on apple eating quality. Although softness and/or mealiness in apples is associated with low quality (Szczesniak and Kahn, 1971) and considered a negative attribute (Daillant-Spinnler *et al*., 1996; Jaeger *et al*., 1998; Symoneaux *et al*., 2012), black and coloured consumers in the Western Cape Province of South Africa, in addition to preferring sweet taste, appear to have some tolerance for mealiness (Van der Merwe, 2013). Researchers previously found no cross-cultural differences in terms of preference for and perception of mealiness in apples (Jaeger *et al*., 1998; Andani *et al*., 2001). Our results, taken together with the Western Cape data, provide a clear picture of South African apple eating quality and appearance preferences.

Attributes driving consumers' actual and conceptual preferences

Consumer preferences are influenced by culture and age differences (Prescott and Bell, 1995; Helgesen *et al.,* 1997; Zandstra and De Graaf, 1998; Racskó *et al*., 2009a, b) as well as ethnicity (Van der Merwe, 2013). Van der Merwe (2013) found that sweet taste was an important driver of liking of apple eating quality for older black and coloured consumers. These consumers disliked sour taste, tolerated mealiness and differed from white and young

consumers from all three ethnicities who preferred firm and sour cultivars but had a strong aversion to mealiness. Results from our study showed that textural attributes such as crispness, hardness, crunchiness and juiciness were important drivers of liking for young white and young Indian consumers. These consumers tolerated sour taste but had a strong aversion to mealiness in agreement with findings of Van der Merwe (2013) for young consumers in the Western Cape Province. Similar to our results, Hungarian children and young adult consumers had a higher preference for firmer cultivars than older consumers (Racskó *et al*., 2009a). It may, however, be erroneous to conclude that young consumers throughout South Africa prefer firm and sour apples considering that the young black consumers in both Gauteng and Kwa-Zulu Natal Provinces preferred sweet taste, tolerated mealiness but disliked sour taste.

Black consumers in both Gauteng and Kwa-Zulu Natal Provinces, as well as older white and older Indian consumers in Gauteng and Kwa-Zulu Natal, respectively, also preferred sweet taste, tolerated mealiness, but disliked sour taste. The sweet taste preference of black consumers in Gauteng and Kwa-Zulu Natal Provinces is in agreement with the findings of Van der Merwe (2013) for black and coloured consumers in the Western Cape Province. Our data for black consumers in Gauteng and Kwa-Zulu Natal Provinces, together with the Western Cape Province data of Van der Merwe (2013) suggest that sweet taste could be the major attribute driving the general apple eating quality preference of black consumers throughout South Africa. Sub-Saharan African populations have reduced taste sensitivity to sucrose, resulting in a preference for higher levels of sweetness (Fushan *et al*., 2009). In addition to cultural and genetic differences, age also affects sweet taste perception (Stevens and Cain, 1993; Fukunaga *et al*., 2005; Bretz *et al*., 2006; Keskitalo *et al*., 2007; Mizuta *et al*., 2008) with older consumers having higher taste preference for sweetness compared to young consumers (Zandstra and De Graaf, 1998). Although older white Gauteng consumers in our study had similar eating quality preferences as black consumers, older white Western Cape Province consumers (Van der Merwe, 2013) had a lower preference for sweet taste and an aversion for mealiness. This is a possible indication that the preference patterns of older white consumers may not be consistent throughout South Africa. The apparent difference in sweet taste preference between older white consumers in the Gauteng and Western Cape Provinces may result from locational differences, which may affect the quality of apple fruit that the respective white consumers are exposed to. White Western Cape consumers reside in

the area where apples are grown. Being the closest market and generally exposed to high quality apples, these consumers may place a premium on firmness rather than sweet taste. Our study also indicated that male consumers generally had a higher sweet taste liking than female consumers. Péneau *et al*. (2006) found gender preference differences among Swiss consumers with female consumers giving higher importance ratings for attributes such as apple taste, aroma, freshness, appearance, type of cultivar, and organically produced fruit. Men generally consume sweet snacks more readily than women (Grogan, 1997).

Fruit peel colour affects consumer perception of fruit quality and therefore also their purchase decisions (Jaeger and MacFie, 2001; Shankar *et al.*, 2010; Steyn, 2012). This is also the case in apple (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002). Yet, there is limited information on consumers' preferences regarding apple appearance. Fischer and Fischer (2008) found that appearance attributes are major drivers of liking and that European consumers preferred bi-coloured fruit with an attractive shiny red over-colour. Cliff *et al*. (2002) found that New Zealand consumers preferred striped red apples, consumers in Nova Scotia, Canada preferred blushed apples, while consumers in British Columbia, Canada were more accepting of a range of apple appearances. Van der Merwe (2013) showed that older black and coloured consumers in the Western Cape Province preferred full red or striped red apples, while young and white consumers preferred full green apples.

Our results showed that young consumers preferred the appearance of green 'Granny Smith' in agreement with their eating quality preference for crispness and sourness. Green peel colour associates positively with sour taste in apples and a variety of fruit products (Clydesdale, 1993; Daillant-Spinnler *et al*., 1996; Shankar *et al*., 2010; Steyn, 2012) and also with perceptions of crispness and firmness in apple (Lau, 1988; Kingston, 1992). Older consumers on the other hand generally disliked the appearance of green 'Granny Smith', reflecting their dislike of sour taste. Black consumers generally liked the appearance of yellow-green 'Golden Delicious', which associated with sweet taste, thereby indicating an association between their appearance and eating quality liking preferences. Yellow background colour in apples is associated with ripeness and such fruit are expected to be sweeter (Richardson-Harman *et al*., 1998; Van der Merwe, 2013).

Familiarity with a specific apple cultivar influences the preference for that cultivar (Harker *et al*., 2003; Van der Merwe *et al*., 2015). This also generally seems to be the case in our study, although there is also some indication that familiarity data should be interpreted with caution. 'Braeburn' was the least known cultivar while older consumers were least familiar with 'Fuji'. These two cultivars were also least preferred in terms of appearance, but this might have been due to the unattractive dull and mottled appearance of the particular fruit of these cultivars used in our study. The low scores are therefore probably rather an indication that consumers find dull red fruit unattractive rather than providing an indication of dislike of 'Fuji' and 'Braeburn' specifically. Steyn *et al*. (2011) found that consumers preference for the appearance of fully red and red blushed pears generally seemed to increase with an increase in chroma, i.e., duller red fruit were liked less. Consumers indicated a greater familiarity with Honeycrisp, even though the availability of this cultivar in South Africa is very limited to a few upmarket Woolworth stores probably due to its red bright colour. The same applies to 'Joya', which has only recently been rebranded and thus should also be unfamiliar to consumers but perhaps was scored high due to its shiny red colour.

Generally, the conceptual preferences of consumers reflected their actual eating quality and appearance preferences. Black, older white and older Indian consumers indicated a preference for sweet taste, a dislike of sour taste and greater tolerance of softness and mealiness in accordance with their actual eating quality preferences in the consumer tests. These preferences were also evident in their conceptual preference for 'Golden Delicious', their liking of full red and striped red apples as well as their dislike of full green apples and 'Granny Smith'. Young Indian and young white consumers' preference indication for full green apples, crisp texture, a tolerance of sour taste and a dislike of softness and mealiness was in agreement with their liking of 'Granny Smith' and their actual eating quality preferences.

Consumer preference clusters for apple eating quality and appearance

We were able to identify three consumer clusters in terms of apple eating quality and appearance preferences. Two of these clusters showed a distinct preference for sweet taste (eating clusters 1 and 2), versus preference for firmness and sour taste in eating cluster 3. Consumers in eating cluster 1 of our study differed from consumers in eating cluster 2 in also

tolerating sourness. Eating cluster 3 consumers, apart from preferring sour taste, also had a predilection for crispness, crunchiness, hardness and juiciness, but disliked mealiness and sponginess. Eating clusters 1 and 2 made up 75% of the total consumer group with an overrepresentation of black and older consumers. Young white and young Indian consumers were overrepresented in eating cluster 3. Studies conducted among British (Daillant-Spinnler *et al*., 1996), Spanish (Carbonell *et al*., 2008), French (Symoneaux *et al*., 2012), Western Cape (Van der Merwe, 2013) and European (Bonany *et al*., 2014) consumers also revealed segments of consumers who either preferred sour taste or disliked it. However, in the study of Van der Merwe (2013), which also identified 3 eating clusters, eating cluster 1 (34% of total consumers), constituting mainly white and the youngest consumers (18-25) liked firm cultivars, tolerated sourness but disliked sweet taste and mealiness. Eating cluster 2 (22% of total consumers), which had an overrepresentation of white and 26-35 age group consumers, had a predilection for sour taste and apple flavour. Eating cluster 3 (44% of total consumers) with an overrepresentation of black and oldest (36+) consumers disliked sour taste. In the application of Ward's clustering analysis to preference data of Spanish consumers by Carbonell *et al*. (2008), 29% of the total consumers liked crispy, hard apples with sour taste, but disliked mealiness, 22% liked sweet taste, tolerated mealiness, but disliked sourness, while 49% of the total consumers had a predilection for apple flavour and textural attributes with medium intensities. Generally, compared to international (mostly European) consumers, a greater percentage of South African consumers have a predilection for sweet taste compared to fewer firm texture and sour taste liking consumers. This can be ascribed to the greater sweet taste preference of black and coloured consumers, with these two ethnicities making up 89% of the South African population (STATSSA, 2014).

Although eating cluster 3 constituted 25% of the total consumer group in our study and consisted predominantly of young white Gauteng and young Indian Kwa-Zulu Natal consumers, there are potentially twice as many black consumers compared to white consumers in Gauteng and five times as many black consumers compared to Indian consumers in Kwa-Zulu Natal within eating cluster 3 when considering consumer demographics within these provinces. Black and white consumers constitute 74% and 20%, respectively of the Gauteng population while in Kwa-Zulu Natal, black and Indian consumers respectively, make up 85% and 9% of the population (STATSSA, 2014). Thus, a considerably higher number of black compared to white and Indian consumers in Gauteng

and Kwa-Zulu Natal, respectively, are partial towards firm and sour apples. The eating quality cluster that was predominantly white in the Western Cape Province and preferring sour tasting cultivars had a good representation of sour liking black and coloured consumers (Van der Merwe, 2013).

Three consumer clusters based on appearance preferences were also identified. Appearance cluster 1, consisting mainly of black and older consumers, preferred red and green/yellow apples but disliked green apples. Appearance cluster 2 (A2), predominantly white, Indian and young consumers, liked red and green apples but disliked dull and mottled coloured fruit, while appearance cluster 3, which constituted mainly young white and young Indian consumers, liked green apples but disliked red apples. The preference patterns of appearance clusters 1 and 3 concur with the general eating quality preference tendencies of the respective sweet preferring and sour preferring consumer groups. Red cultivars, as well as green/yellow apple peel colour are associated with sweet taste, while green cultivars associate with sourness (Daillant-Spinnler *et al*., 1996; Carbonell *et al*., 2008; Steyn, 2012; Van der Merwe, 2013). Considering that 'Fuji' and 'Topred' associated with sweet taste, while 'Braeburn' and 'Granny Smith' associated with sourness in Paper 1 of our study, the preferences of appearance cluster 2 were not consistent with their eating quality preferences. A2 consumers seemingly gave high scores to apples that were attractive to them and were unfamiliar with the appearance of their preferred apples in terms of eating quality.

Consumer preference of apple fruit at progressive maturity levels

Our study showed gender, ethnic and age group differences among Western Cape Province consumers in relation to the eating quality and appearance of riper 'Topred' fruits, as well as the appearance of riper 'Golden Delicious' in 2013 and 2014. Consumer preference declined slightly with increasing shelf-life of 'Golden Delicious' in both seasons, probably due to relatively small changes in eating quality attributes during shelf-life. Fruit firmness values for the different shelf-life durations for Golden Delicious cultivar in both seasons differed by less than the 6 N, which is purportedly the minimum fruit firmness difference at which consumers can detect texture differences in apple fruit (Harker *et al*., 2002). Older black, older coloured as well as black male and coloured male consumers were partial to the texture quality of riper 'Topred' apples in 2013 compared to other consumer groups, while coloured consumers of all

ages preferred the texture quality of riper, softer and more mealy 'Topred' apples in 2014 compared to black and white consumers. White South African consumers are considered European-like in their food preferences (Viljoen and Gericke 2001), while Hungarian young consumers were found to prefer firmer apple cultivars (Racskó *et al*., 2009a). The actual texture quality liking of older coloured consumers was consistent with their greater preference indication for a soft ripe texture, slight and high degree of mealiness, as well as spongy texture compared to other consumer groups. Likewise, the increasing dislike for ripening 'Topred' apples among young and older white consumers was in close association with their generally higher conceptual preference indication for crisp crunchy texture, as well as sour taste. Van der Merwe (2013) and Paper 1 of our study suggested a greater tolerance for mealiness among older black and coloured consumers. Paper 1 also suggested a greater tolerance of mealiness among male consumers. Black consumers disliked the eating quality of ripe 'TR' apples to the same extent as white consumers, thus the apparent tolerance of black consumers for mealiness (Van der Merwe, 2013; Paper 1) is not because they like mealy apples, but is due to their generally very high preference of sweet taste and the sweet tasting cultivars. Mealiness and sweetness tend to be correlated in apples since both these attributes increase during ripening (Jaeger *et al*., 1998; Richardson-Harman *et al*., 1998).

Older coloured consumers as well as male consumers preferred the appearance of more yellow as compared to green 'Golden Delicious' fruit while young and white consumers generally preferred the greener appearance of less ripe 'Golden Delicious'. Yellow ground colour associates with ripeness and sweet taste (Lau, 1988; Kingston, 1992; Richardson-Harman *et al*., 1998; Steyn, 2012) as well as with softness (Richardson-Harman *et al*., 1998), while green peel colour associates with firmness (Richardson-Harman *et al*., 1998). The ethnic, age and gender-related differences in peel colour preferences in 'Golden Delicious' seem to correspond with the eating quality preferences for softer and sweet versus firmer and more sour apples among these consumer groups. According to Lau (1988), Kingston (1992), Richardson-Harman *et al*. (1998) and Steyn (2012), the yellowing of fruit ground colour is usually a very good indicator of maturity. However, the ground colour change that was observed in 'Golden Delicious' apples with increasing shelf life, did not reliably indicate fruit eating quality. Ground colour changed considerably over the shelf-life period while eating quality changed comparatively much less.

White consumers generally disliked the appearance of 'TR' fruits compared to black and coloured consumers consistent with their generally greater preference for crisp and firm apples. Consistent with their generally greater preference for riper and sweeter fruits and in agreement with previous findings (Van der Merwe, 2013; Paper 1), older as well as male consumers showed a higher preference for the appearance of riper 'Topred' apples. This is interesting, considering that 'Topred' apples of different ripeness levels differed very little in appearance due to ground colour change being masked by the overlaying anthocyanins. Steyn (2012) discussed the difficulty of assessing fruit maturity in fruits where ground colour change is concealed. Clydesdale (1993) showed that red peel colour associates with sweet taste and Steyn (2012) ascribed this taste and colour association to the concomitant increases in both red colouration and sweetness during ripening of many fruits.

Factors influencing consumers' apple purchase decisions and shopping patterns

Our results showed that apple peel colour was the most important factor that influenced consumer purchase decisions in the Gauteng and Kwa-Zulu Natal Provinces. This is in agreement with findings of Van der Merwe (2013) for Western Cape Province consumers, suggesting that peel colour is the most important pre-purchase factor considered by South African consumers in agreement with previous findings (Crassweller and Hollender, 1989; Saure, 1990; Cliff *et al.*, 2002). In addition to colour, fruit size was important to both younger (18-25) and older (26+) consumers in our study, but older consumers also considered the price of apples. Racskó *et al*. (2009b) found that Hungarian consumers younger than 25 years indicated that taste was the most important attribute that influenced their choice of apple, followed by fruit size and colour. Hungarian consumers between the ages of 25 and 50 also indicated price as an important factor influencing their purchase decisions (Racskó *et al*., 2009a). Our study showed that black consumers in Kwa-Zulu Natal rated price as more important compared to the other consumer groups. This observation is probably as a result of the predominance of black South African consumers in the lower Living Standard Measure (LSM)® groups with less dispensable income (Wortley and Tshwaedi, 2002; Holborn, 2012) and a higher price sensitivity. Consumers with lower income levels tend to exhibit higher price sensitivity (Racskó *et al*., 2009b). White consumers in Gauteng and black consumers in Kwa-Zulu Natal considered the indication of cultivar name on the packaging an important factor influencing their purchase decisions probably because they gave the highest indication

of familiarity with most of the cultivars studied. Van der Merwe (2013) found that cultivar loyalty and cultivar name indication on the packaging were important factors influencing the purchase decisions of white consumers in the Western Cape Province. This pattern probably suggests that indicating cultivar name on packaging plays a large role in the purchase decision of white consumers throughout South Africa and also to consumers who tend to be familiar with apple cultivars.

In addition to evaluating the factors that influence consumer's decision to purchase apple, our study also focused on assessing possible shopping patterns. More young black consumers buy fresh fruits themselves compared to young white and young Indian consumers, probably because most black students in South Africa reside in dormitories and are responsible for buying their own food. Young white and young Indian students in South Africa are most likely to stay in campus residences and therefore they neither cook nor buy food themselves or have their parents being responsible for buying fresh fruits. Our study also showed that more female consumers buy fresh fruits compared to male consumers in agreement with literature that females generally consume more fruit and vegetables and apples specifically than males (Baker and Wardle, 2003; Pèneau *et al*., 2006). In addition, Vermeulen and Biénabe (2010) found that the main shopper in the household for fresh fruits mostly comprised of the wife, mother or female partner.

Results from our study in relation to the shop outlets from which apples are purchased by specific consumer groups showed that black, young white Gauteng and young Indian Kwa-Zulu Natal consumers buy apples more from Pick 'n Pay than from the other shops listed in the study, viz. Checkers, Food Lovers Market, Fruit & Veg, green grocery, Shoprite, Spar, Woolworths, hawker or other sources. Older black Kwa-Zulu Natal consumers also buy apples from Shoprite as much as they buy from Pick 'n Pay while older white Gauteng consumers buy apples from Pick 'n Pay, Woolworths, Fruit & Veg and Spar comparably and more than from other shops. The older Indian Kwa-Zulu Natal consumers buy apples from Pick 'n Pay, Fruit & Veg and Checkers and they buy apples from Woolworths as much as they buy from Checkers.

Particular neighbourhoods, as well as shop outlets in South Africa, are generally characterised and favoured by consumers belonging to specific LSM groups with dispensable income increasing from LSM 1 (115.84 US dollars per month) to LSM 10 (2,350.01 US dollars per month) (Wortley and Tshwaedi, 2002; Bishop, 2012; Holborn, 2012). Wortley and Tshwaedi (2002) as well as Holborn (2012) showed that although specific LSM groups are not solely characterised by a particular ethnic group, LSMs 1-6 are dominated by black consumers, whereas LSMs 8-10 consist predominantly of white consumers. Woolworths and Checkers target consumers in the LSM 8-10 groups (Woolworths Holdings Limited, 2012; Shoprite Holdings Limited, 2014) while Spar and Fruit & Veg operates across the entire LSM spectrum (Vermeulen and Biénabe, 2010; Integrated Report, 2014) explaining the shopping preferences of white and Indian consumers. Vermeulen and Biénabe (2010) reported that all LSM groups preferred Pick ‘n Pay and Fruit & Veg, LSMs 7 and 8 preferred Shoprite and Checkers, while LSM 9 and 10 preferred Woolworths for fresh fruit purchases. Pick ‘n Pay and Shoprite target consumers in the LSM 4-7 group (Pick ‘n Pay Annual Results, 2012; Shoprite Holdings Limited, 2014) possibly explaining why black consumers generally purchase apples from Pick ‘n Pay and older black Kwa-Zulu Natal consumers buy apples from Shoprite, as well. Although most of the consumers in our study were students, the white and Indian consumers had the highest percentages of professionals and administrative staff, thus explaining their apple purchase from Woolworths, Fruit & Veg, Spar and Checkers in addition to Pick ‘n Pay. However, differential purchasing patterns are not unique to South Africa. A specialty regional chain grocery store in Tucson, Arizona attracted relatively older shoppers with higher income and more graduate or professional degrees compared to a local cooperative (Thompson and Kidwell, 1998).

Implications for retailers, marketers and distributors

There are three groupings of apple consumers based on taste preferences. Although, the three groupings identified in Western Cape showed distinct preference patterns, two out of the three clusters in Gauteng and Kwa-Zulu Natal were quite similar. Thus, allocating shelf space to different cultivars based on the demographics and likely preferences of the clientele could potentially increase apple sales by ensuring consumer satisfaction. For example, local marketers and distributors could supply the geographical location where black and coloured consumers are concentrated with sweet tasting cultivars such as Fuji (red over colour), Topred (full red colour) and Golden Delicious (green/yellow colour). However, marketers

and distributors should not only target cultivars at the predominant consumers within specific consumer segment but also at the seemingly minor group of consumers within each cluster. This is because there is a good representation of black consumers who prefer firm and sour tasting cultivars. Young consumers as well as older white consumers in the Western Cape Province should be supplied with crisp, firm and sour cultivars such as full green Granny Smith. The general preference of female consumers' for the cultivar Pink Lady® suggests that marketers were successful in building a positive gender-based brand for this cultivar. Future studies could be carried out among young, adventurous and fun-loving people to determine whether current efforts to re-brand 'Sundowner®' as 'Joya™' among young consumers have been successful. 'Golden Delicious' apples with a more yellow ground colour, which is associated with increased ripeness, softness and mealiness and that will normally not sell on other African markets that import apples from South Africa, could be supplied to coloured consumers and older coloured consumers in particular. Considering that coloured consumers are generally partial to riper, softer and yellow peel coloured 'Golden Delicious', the threshold background colour at which 'Golden Delicious' fruit is removed from shelves could be less strict in shop outlets in predominantly coloured neighbourhoods. Basing consumers eating quality expectations of 'Topred' fruit on its peel colour can be misleading since the external colour does not give an indication of fruit's maturity and internal quality.

For relatively unfamiliar cultivars such as Fuji, it might be necessary to entice consumers to buy the fruit through in-shop tastings and promotions highlighting the positive eating quality drivers of the fruit, such as sweet taste. In order to maximise sales, cultivar names should be indicated on packaging in shop outlets throughout South Africa that target especially white consumers. In addition, Pick 'n Pay should stock a wide range of apple cultivars. Shoprite should stock more sweet tasting cultivars while Woolworths, Fruit & Veg, Checkers and Spar should stock firm, moderately sour, as well as sweet tasting cultivars.

Limitations and future research

Constraints in the study conducted on the use of commercial cultivars for assessing drivers of consumer liking pertained to correlations between sensory attributes that made it difficult to single out specific taste and texture attributes in relation to specific cultivars. For example, an

attribute such as sweet taste was firmly entwined with mealiness and softness, while sour taste was linked with attributes relating to firmness. Therefore, the identification of isolated sensory attributes that drove consumer preferences was complicated. Although black and older consumers in Gauteng and Kwa-Zulu Natal Provinces showed tolerance of mealiness, the mealiest cultivar had a mealiness score of 6 on a 100-point intensity scale. It was therefore difficult to ascertain if such consumers liked mealiness or probably just preferred sweet taste. In terms of determining consumer preference for the eating quality and appearance of fruit of different ripeness levels, we might have achieved clearer results if differences between ripeness categories were more distinct. The methodology of future studies, in terms of storage temperatures and durations, should be adapted in order to attain a crisp and firm apple at the one end as well as a much wider variation in softness and/or mealiness levels. In addition, clearer results in terms of the role of appearance in taste liking could be obtained if consumers are made to view an apple and score it for appearance and then score a section of the same apple for taste. This would also more closely simulate real life situations where assessment of appearance by consumers precedes tasting and influences the taste experience. Van der Merwe *et al*. (2015) found that consumers indicated a higher liking for the eating quality of 'Starking' apples if they were misled to believe that they were tasting 'Cripps' Pink' apples by prior viewing of a photograph of this more desirable cultivar.

The young consumers who partook in the study were mostly students at either University of Pretoria, Durban University of Technology or University of Stellenbosch and therefore not representative of the total consumer group younger than 25 in the Gauteng, Kwa-Zulu Natal and Western Cape Provinces. Hence, the sourcing of young consumers should be improved for future studies in order to verify the preferences of young consumers. There was a much lower representation of older consumers compared to young consumers and older consumers were mostly between 26 and 40 in age. There is therefore likelihood that our findings pertaining to older consumers were not representative of the entire older age group. Indian consumers in general and older Indian consumers in particular were not well represented. Considering that female consumers in most instances are responsible for buying fresh fruit for the household, the overrepresentation of females in our study was not a concern. However, future studies could focus on ascertaining the influence that different classes of female consumers (e.g. single, married and with children or married but without children)

have on the purchase of apple fruit. Preference patterns within the same household could also be studied.

Africa is currently a thriving market for South African apples, accounting for 28% of total export volume and 75% of 'Golden Delicious' apples exported (HORTGRO, 2015). Studies could be carried out in main African markets for South African apples such as Nigeria, Ghana, Angola and Zambia to determine the drivers of liking of consumers in these countries and to ascertain their preferences for apple cultivars other than 'Golden Delicious'. As was done in this study for Western Cape consumers, the response of black consumers in other African countries to apple ripeness levels and associated textural, taste and appearance attributes should be ascertained. Peel colour appears to be a major purchase factor in 'Golden Delicious' (Henk Griessel, personal communication, July 23, 2015) and this should be studied in more detail. A future study could also focus on assessing the satisfaction or dissatisfaction of different consumer groups with apple cultivars with different appearances and relate these results to repurchase decisions. The contribution of different colour components, i.e. hue angle, chroma and lightness, to the attractiveness of apples to consumers could be explored in more detail while the interaction between fruit appearance, specifically with regard to various blemishes, and apple price can also be investigated.

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APPENDICES

Appendix 1

Descriptors of apple quality attributes (adapted from Daillant-Spinnler *et al*., 1996).

Quality attributes	**Description of quality attributes**
Sweet taste	One of basic tastes, e.g. sucrose
Sour taste	One of basic tastes, e.g. citric acid
Apple flavour	Associated with typical apple flavour
Astringency	Dries the surface of the mouth, i.e. tannic acid
Bitterness	One of basic tastes e.g. quinine, caffeine
Crispness	Sound generated when biting into apple with front teeth
Hardness	Force to bite into apple with molar teeth
Crunchiness	Ease of disintegration when chewing with molar teeth
Juiciness	Amount of juice released by sample during chewing
Mealiness	Over-ripe soft, dry and floury texture
Sponginess	Spongy or springy texture
Peel toughness	Measure of how tough the peel is

Appendix 2

ACCEPTABILITY OF COMMERCIAL APPLES

NAME OF JUDGE: _____ **CONTACT NUMBER (Mobile or Landline):** _____ **JUDGE NO:** _____

PLEASE CIRCLE WHICHEVER IS APPLICABLE

GENDER:

Male / Female

AGE:

18-25 / 26-30 / 31 – 40 / 41 – 50 / 51-60 / 61+

ETHNIC GROUP:

Black / Coloured / White / Indian
Other:_____

EDUCATION:

Grade 11 (Standard 9) or below / Grade 12 (Matric) / Diploma or degree

WHAT IS YOUR **CURRENT EMPLOYMENT?**

Student / Assistant / Administrative / Blue collar/ Professional
Other:_____

WHO IS PRIMARILY RESPONSIBLE FOR **BUYING FRESH FRUIT** FOR YOUR HOUSEHOLD?

Yourself / Spouse / Parents / Other:_____

HOW OFTEN DO YOU **BUY FRESH FRUIT?**

Daily / 2-3 times a week / Once a week / 2-3 times a month / Once a month / Never

HOW OFTEN DO YOU **BUY APPLES?**

Daily / 2-3 times a week / Once a week / 2-3 times a month / Once a month / Never

WHERE DO YOU USUALLY **BUY APPLES?**

Woolworths / PicknPay / Shoprite / Checkers / Fruit & Veg / Spar / Hawker /Other: _____

HOW OFTEN DO YOU **EAT APPLES?**

Daily / 3-5 times a week / Once a week / 2-3 times a month / Once a month / Never

IN WHAT STATE DO YOU OFTEN **EAT YOUR APPLES?**

Eat alone, fresh / Eat fresh in salads / Cooked / Baked in pies or baked whole / Other: _____

Appendix 3

How much do you like the TASTE of the apples?

1. Taste the samples **IN THE ORDER PRESENTED.** Take **A GENEROUS BITE** from each sample & rinse your mouth with **WATER** between samples.
2. **CIRCLE** the **NUMBER** next to the **PREFERRED DEGREE OF LIKING.**

CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely
CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely
CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

PLEASE TURN TO THE NEXT PAGE

Appendix 4

How much do you like the APPEARANCE of the apples?

IN EACH CASE **CIRCLE** THE **NUMBER** NEXT TO THE **PREFERRED DEGREE OF LIKING**



CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

PLEASE TURN TO THE NEXT PAGE

Appendix 5

How much do you like the APPEARANCE of the apples?

IN EACH CASE **CIRCLE** THE **NUMBER** NEXT TO THE **PREFERRED DEGREE OF LIKING**

CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

PLEASE TURN TO THE NEXT PAGE

Appendix 6

How much do you like the APPEARANCE of the apples?

IN EACH CASE **CIRCLE** THE **NUMBER** NEXT TO THE **PREFERRED DEGREE OF LIKING**

CODE:		CODE:		CODE:	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

PLEASE TURN TO THE NEXT PAGE

Appendix 7

GENERAL QUESTIONS

IN EACH CASE **CIRCLE** THE **NUMBER** THAT **BEST FITS YOUR ANSWER**

Indicate your degree of liking of the APPLE TASTE & TEXTURE attributes 1___2___3___4___5___6___7___8___9 Dislike Extremely — Not sure — Like Extremely	
Prominent Apple Aroma (Smell)	1___2___3___4___5___6___7___8___9
Sour Apple Taste	1___2___3___4___5___6___7___8___9
Sweet Apple Taste	1___2___3___4___5___6___7___8___9
Prominent Apple Taste	1___2___3___4___5___6___7___8___9
Bland or Slight Apple Taste	1___2___3___4___5___6___7___8___9
Bitter Taste	1___2___3___4___5___6___7___8___9
Astringent or Dry Mouthfeel	1___2___3___4___5___6___7___8___9
Juiciness	1___2___3___4___5___6___7___8___9
Mealiness (slightly dry or floury texture)	1___2___3___4___5___6___7___8___9
Crisp Texture	1___2___3___4___5___6___7___8___9
Spongy Texture	1___2___3___4___5___6___7___8___9
Soft, ripe Texture	1___2___3___4___5___6___7___8___9
Slight internal browning	1___2___3___4___5___6___7___8___9

How important are the following aspects when buying / eating APPLES? 1___2___3___4___5___6___7___8___9 Not important — Not sure — Extremely important	
Purchasing price of APPLES	1___2___3___4___5___6___7___8___9
Colour of the APPLE	1___2___3___4___5___6___7___8___9
Size of the APPLE	1___2___3___4___5___6___7___8___9
Shape of the APPLE	1___2___3___4___5___6___7___8___9
I am extremely loyal to **specific apple cultivars**	1___2___3___4___5___6___7___8___9
Specific cultivar name must be **indicated** on packaging	1___2___3___4___5___6___7___8___9
I am always **familiar** with the cultivars I purchase	1___2___3___4___5___6___7___8___9
How important is it to **peel an apple** before eating it?	1___2___3___4___5___6___7___8___9

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Appendix 8

GENERAL QUESTIONS

IN EACH CASE **CIRCLE** THE **NUMBER** THAT **BEST FITS YOUR ANSWER.**

Indicate your degree of liking of the following APPLE PEEL APPEARANCES

1___2___3___4___5___6___7___8___9

Dislike Extremely Not sure Like Extremely

	**Green**	**1___2___3___4___5___6___7___8___9**		**Red bi-coloured** (more than 50% red coloured)	**1___2___3___4___5___6___7___8___9**
	**Red**	**1___2___3___4___5___6___7___8___9**		**Red blushed** (less than 50% red coloured)	**1___2___3___4___5___6___7___8___9**
	**Yellow**	**1___2___3___4___5___6___7___8___9**		**Pink bi-coloured** (more than 50% pink coloured)	**1___2___3___4___5___6___7___8___9**
	**Red striped**	**1___2___3___4___5___6___7___8___9**		**Pink blushed** (less than 50% pink coloured)	**1___2___3___4___5___6___7___8___9**

Please turn to the last page

Appendix 9

GENERAL QUESTIONS

Indicate your degree of liking of the following APPLE CULTIVARS

1____2____3____4____5____6____7____8____9

Dislike Extremely Not sure Like Extremely

Cultivar	Tick (√) if you are NOT familiar with a cultivar	If you ARE FAMILIAR with a cultivar, indicate your degree of liking by circling the correct number
Golden Delicious	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Royal Gala	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Topred	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Braeburn	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Honeycrisp	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Fuji	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Cripps Pink	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Sundowner	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**
Granny Smith	*I am NOT familiar with this cultivar*	**1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9**

PLEASE COLLECT A GIFT AS YOU HAND IN YOUR COMPLETED QUESTIONNAIRE!!

Appendix 10

APPLE CONSUMER TEST

NAME OF JUDGE: _____CONTACT NUMBER (Mobile or Landline): _____JUDGE NO: _____

PLEASE CIRCLE WHICHEVER IS APPLICABLE

GENDER: Male / Female	**WHEN IN SEASON**, HOW OFTEN DO YOU **BUY APPLES?** Daily / 2-3 times a week / Once a week / 2-3 times a month / Once a month / Never
AGE: 18-25 / 26-30 / 31 – 40 / 41 – 50 / 51-60 / 61+	WHERE DO YOU USUALLY **BUY APPLES?** Woolworths / PicknPay / Shoprite / Checkers / U-SAVE / Fruit & Veg / Food Lover's Market / Spar /Hawker /Other: _____
ETHNIC GROUP: Black / Coloured / White / Indian / Other:_____	**WHEN IN SEASON**, HOW OFTEN DO YOU **EAT APPLES?** Daily / 2-3 times a week / Once a week / 2-3 times a month / Once a month / Never

PLEASE TURN TO THE NEXT PAGE

Appendix 11

Group A

How much do you like the overall TASTE and TEXTURE of the SLICED APPLES?

1. Taste samples IN THE ORDER PRESENTED. Take A GENEROUS BITE from each sample, rinse your mouth with WATER between samples
2. **CIRCLE** the **NUMBER** next to the **PREFERRED** degree of liking

	CODE		CODE		CODE		CODE		CODE	
How much do you like the **Overall Texture**	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

How much do you like the **Overall Taste**	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

Appendix 12

Group B

How much do you like the overall TASTE and TEXTURE of the SLICED APPLES?

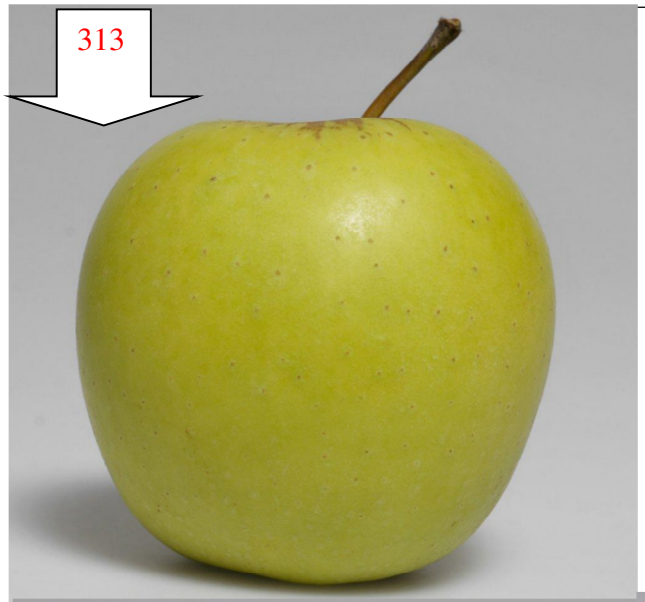
1. Taste samples IN THE ORDER PRESENTED. Take A GENEROUS BITE from each sample, rinse your mouth with WATER between samples
2. **CIRCLE** the **NUMBER** next to the **PREFERRED** degree of liking

	CODE		CODE		CODE		CODE		CODE	
How much do you like the **Overall Texture**	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

How much do you like the **Overall Taste**	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
	8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike	5	Neither like nor Dislike
	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

Please turn to next page for PHOTOGRAPHS

Appendix 13

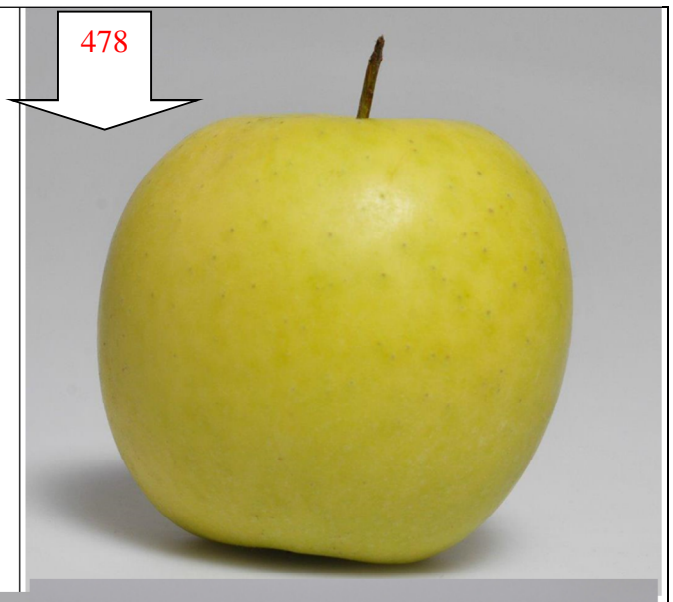


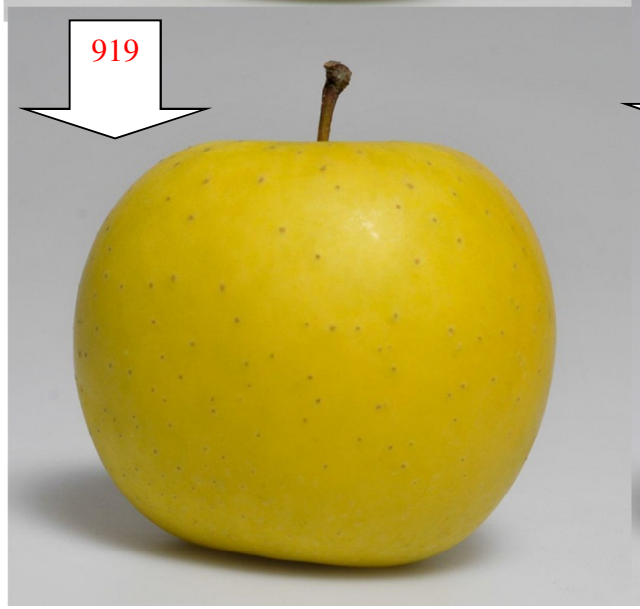
Group C

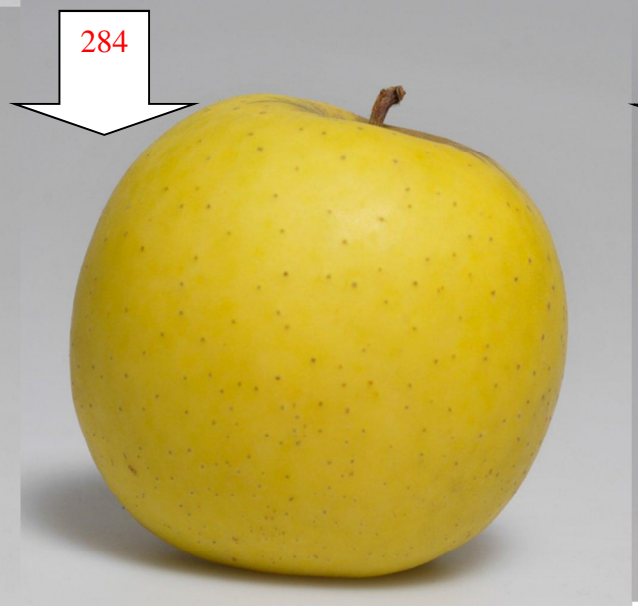
How much do you like these

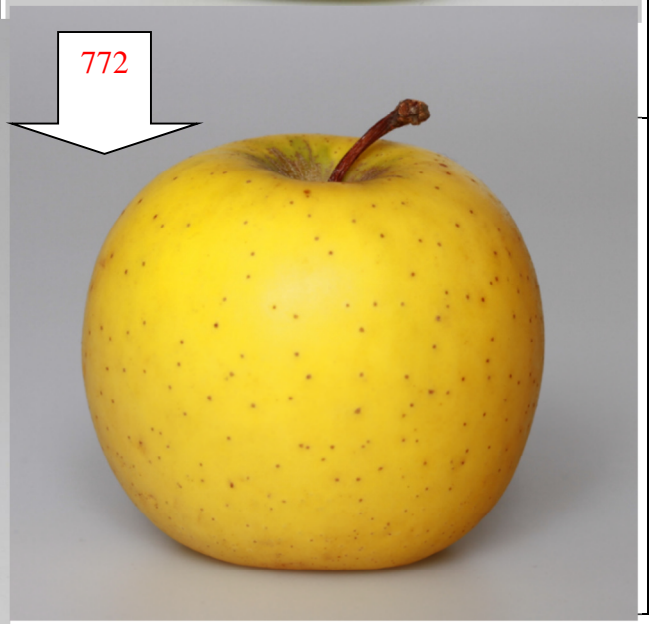
APPLE APPEARANCES?

(Score on the page to your right)









Appendix 14

CODE 313	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Like extremely
1	Dislike extremely

Group C

Indicate your degree of liking of the

APPLE APPEARANCES

as indicated on the page to your left

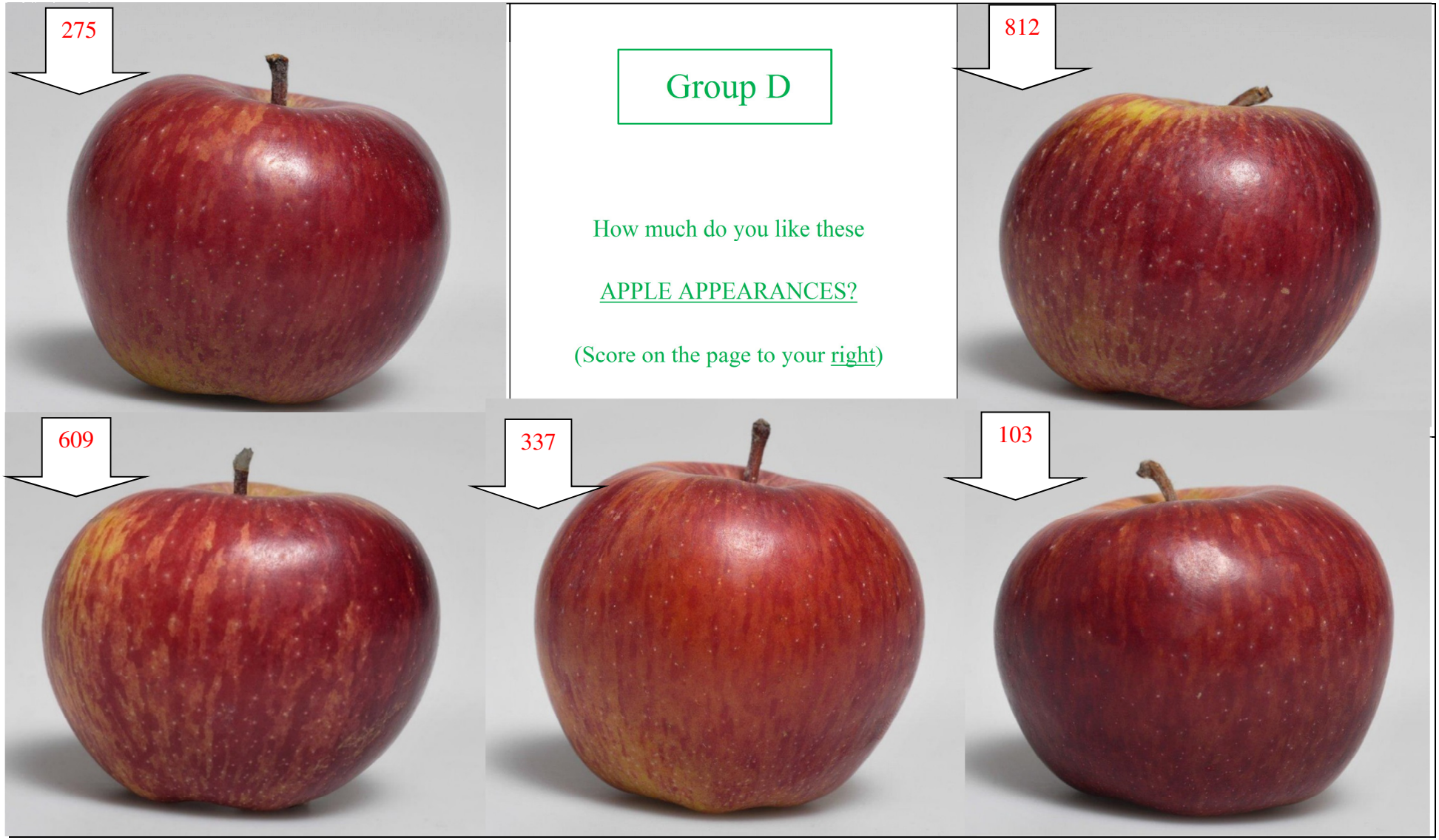
CODE 478	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 919	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 284	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 772	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Appendix 15



Appendix 16

CODE 275

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Like extremely
1	Dislike extremely

Group D

How much do you like these

APPLE APPEARANCES?

(Score on the page to your left)

CODE 812

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 609

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 337

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

CODE 103

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Appendix 17

How do you like the following TASTE & TEXTURE ATTRIBUTES when it comes to APPLES?

In each case, CIRCLE the NUMBER that best fits your answer

	1 2 3 4 5 6 7 8 9 Dislike Extremely — Not sure — Like Extremely
Crisp, crunchy apple texture	1 2 3 4 5 6 7 8 9
Soft, ripe apple texture	1 2 3 4 5 6 7 8 9
Apple with a slight, mealy texture	1 2 3 4 5 6 7 8 9
Apple with a high degree of mealiness (dry or floury texture)	1 2 3 4 5 6 7 8 9
Spongy texture	1 2 3 4 5 6 7 8 9
Very juicy apple	1 2 3 4 5 6 7 8 9
Moderately juicy apple	1 2 3 4 5 6 7 8 9
Slightly juicy apple	1 2 3 4 5 6 7 8 9
Sweet apple taste	1 2 3 4 5 6 7 8 9
Sour apple taste	1 2 3 4 5 6 7 8 9
Prominent apple flavour	1 2 3 4 5 6 7 8 9
Slight bitter taste	1 2 3 4 5 6 7 8 9
Apple with an astringent or dry mouthfeel	1 2 3 4 5 6 7 8 9

PLEASE COLLECT A GIFT AS YOU HAND IN YOUR COMPLETED QUESTIONNAIRE AT THE DOOR!!