Consumer acceptance of Cheddar cheese: Intrinsic, extrinsic and socio-demographic influences

Claire Goosen

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Supervisors

M. Muller, Department of Food Science, Stellenbosch University

Prof. N Vink, Department of Agricultural Economics, Stellenbosch University

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DECLARATION

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Candidate: Claire Goosen

Date: March 2014

ABSTRACT

The objective of this study was to determine the sensory characteristics of Cheddar cheese that drive consumer acceptance. In addition, it investigated whether specific sensory profiles would satisfy specific consumer segments to ultimately facilitate greater acceptance and consumption of Cheddar cheese.

A trained panel applied descriptive sensory analysis (DSA) to characterise the sensory attributes of six commercially produced cheeses ranging in maturity from 1 to 32 months. The cheese samples were differentiated by appearance, aroma, flavour and textural attributes. A consumer panel comprising of 115 target consumers rated preference for the cheeses on a 9-point hedonic scale. Moreover consumers completed a screener designed to collect socio-demographic information and opinions on cheese and cheese products. Instrumental colour analysis was performed on the cheese samples and in-depth consumer opinions and attitudes towards cheese were examined using the focus group technique.

Analysis of variance (ANOVA) was conducted on the sensory and instrumental data, as well as the consumer liking and perception data. Additionally, a t-test was performed at a 5% significance level to determine the direction of the difference between the mean values.

Multivariate analyses were performed on the sensory and consumer data to determine whether relationships existed between sample attributes and consumer liking. Consumer acceptability scores were segmented by agglomerative hierarchical clustering (AHC) using Ward's test. ANOVA was performed on the consumer data per cluster for colour liking, texture liking, flavour liking and overall liking. Partial least squares regression (PLS) was performed in an attempt to relate consumer degree of liking data, the social-demographic and attitudinal data, as well as the sensory and instrumental data.

The younger cheeses; Gouda at one month, Edam at two months and Cheddar at 4 months were characterised as glossy, with a buttery and creamy aroma; creamy flavour, salty and slightly sour taste combined with lingering cheese flavour. Textures were described as creamy, springy and rubbery. Sensory attributes of visible white crystals, moisture seepage, brothy and Cheddar aromas; brothy, Cheddar and prickle flavours together with textural attributes of firm, hard, crumbly, grainy and teeth-coating characterised the aged Cheddar cheeses.

Flavour development was not progressive as the cheeses aged and atypical flavour development was identified in the Cheddar cheese aged to 8 and 15 months, respectively. Flavour followed by price and convenience drive cheese purchase amongst this group of consumers. From a sensory perspective, glossy appearance, a red hue and yellow colour drive cheese colour liking. Texture liking is driven by springy and hard attributes. Flavour liking is driven by cooked milk, buttery and creamy aroma and creamy flavour. Finally overall cheese liking is driven by glossy appearance; cooked milk, buttery and creamy aroma; creamy flavour; springy and creamy texture; specific instrumental colour values, as well as fat, moisture and salt content.

Three clusters per variable of colour, texture, flavour and overall liking of cheese were identified through segmentation performed on the preference data. Results indicate that consumers are not homogenous in their sensory requirements, attitudes and behaviour towards cheese. Based on the consumer preference for

specific sensory characteristics of cheese, consumer segments can be identified and cheese can be optimised to satisfy these sensory requirements.

UITTREKSEL

Die doel van hierdie studie was eerstens om te bepaal watter spesifieke sensoriese eienskappe van Cheddarkaas verbruikersaanvaarbaarheid dryf, en tweedens om verbruikersdata te segmenteer ten einde vas te stel of verskillende verbruikersegmente verskillende voorkeure het wat betref Cheddarkaas. Kennis hiervan sal uiteindelik bydra tot verhoogde verbruikerstevredentheid, en dus verhoogde verkope van Cheddarkaas op die plaaslike mark.

Beskrywende sensoriese analise en ’n opgeleide paneel is gebruik om die sensoriese eienskappe van ses kommersiële kaas variante te bepaal. Instrumentele kleuranalise is ook bepaal. Die monsters kaas het gewissel in ouderdom (van 1 tot 32 maande veroudering), asook in voorkoms, aroma, geur, smaak en teksturele eienskappe. ’n Verbruikerspaneel bestaande uit 115 individue het die voorkeur en aanvaarbaarheid van die ses variante kaas ge-evalueer deur gebruik te maak van die 9-punt hedoniese skaal. Sosio-demografiese inligting en verbruikeropinies betreffende kaas is ook versamel. Ten laaste is die fokusgroep tegniek gebruik om in-diepte inligting te verkry wat betref verbruikeropinies en –houdings ten opsigte van Cheddarkaas.

Analise van variansie (ANOVA) is op sensoriese, instrumentele en verbruikersdata toegepas. T-toets is by ‘n betekenispeil van 5% uitgevoer om te bepaal of daar per eienskap betekenisvolle verskille tussen monstergemiddeldes was. Meerveranderlike analise is uitgevoer op die sensoriese en verbruikerdata ten einde te bepaal of spesifieke sensoriese produkeienskappe verbruikersvoorkeur dryf. Ward se statistiese groepering is gebruik om te bepaal of die verbruikers in verskillende voorkeursegmente gegroepeer kan word. Hierna is ANOVA op elke segment uitgevoer ten einde per segment verbruikersvoorkeur van die onderskeie produkte te bepaal wat betref voorkoms, geur en tekstuur. Meervoudige regressie analise is toegepas om die verwantskap tussen verbruikervoorkeur-, houding- en sosio-demografiese eienskappe van die verbruikers te bepaal, asook tussen die sensoriese en instrumentele produkeienskappe.

Die kase wat vir ‘n kort tydperk verouder is, m.a.w. Gouda, Edam en Cheddar na 4 maande veroudering is beskryf as glansend, met ‘n ryk botter en romerige aroma, romerige geur, sout en effense suur smaak, asook ‘n standhoudende kaasgeur. Teksturele eienskappe van hierdie drie kaassoorte is beskryf as romerig, veerkragtig en effe rubberig. Die Cheddar kase wat langer verouder is, het tekens getoon van sigbare wit kristalle en sinerese op die kaasoppervlak, ‘n prikgevoel op die tong, asook sopagtige (“brothy”) en Cheddaragtige aromas en geure. Die teksturele eienskappe van die verouderde Cheddar kase is beskryf as ferm, hard, krummelagtig en greinerig, asook met’n geneigdheid van die kaas om aan die tande vas te kleef. Geurontwikkeling het nie progressief plaasgevind soos die kase verouder het nie. Die Cheddar kase wat onderskeidelik vir 8 en 15 maande verouder is, het atipiese geurontwikkeling getoon.

Belangrike faktore wat tydens die aankoop van kaas’n rol speel, en dus voorkeur dryf is eerstens geur, tweedens prys en derdens produk-gemak. Sensoriese aspekte wat voorkeur dryf, is ‘’n glansende voorkoms en effe rooierige-gelerige kleur. Tekstuur voorkeure sluit in veerkragtiheid en hardheid, terwyl geur voorkeure die volgende insluit: romerige, botterige en melk aromas, asook ‘n romerige geur. In die geheel gesien, dryf die volgende eienskappe dus verbruikersvoorkeur: kaas met ‘n glansende voorkoms, geure soos botteragtig, roomagtig en melkerig en teksture soos veerkragtig en romerig. Voedinstofinhoud beïnvloed ook verbruikersvoorkeur, nl. soutinhoud, vetinhoud en voginhoud. Segmentasie van verbruikersdata het getoon

dat die onderskeie verbruikersegmente nie ooreenstem wat betref hul verbruikersvoorkeure, houdings en persepsies van kaassorte nie. Die resultate het egter spesifike sensoriese rigtingwysers geidentifiseer wat die bedryf kan gebruik om kaas te produseer vir elk van die onderskeie marksegmente.

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GLOSSARY OF ABBREVIATIONS

%	-	Percent sign (indicating percentage)
°C	-	Degrees Celsius
µg	-	Microgram
AD	-	Anno Domini
ANOVA	-	Analysis of Variance
CEP	-	Cell envelope proteinases
cm	-	Centimetre
CO_2	-	Carbon Dioxide
DF	-	Degree of Freedom
DSA	-	Descriptive Sensory Analysis
F-value	-	Measurement of distance between individual distributions. As F goes up, P goes down (i.e., more confidence in there being a difference between two means). To calculate: (Mean Square of X / Mean Square of Error)
g	-	Gram
h	-	Hours
H_2S	-	Hydrogen sulphide
kg	-	Kilogram
kJ	-	Kilojoule
LAB	-	Lactic acid bacteria
Lc.	-	Lactococcus
LSD	-	Least Significant Difference
MFT	-	2-methyl-3-furanthiol
mg	-	Milligram
ml	-	Millilitre
mo	-	Months
MSG	-	Mono-sodium glutamate

NaCl	-	Sodium Chloride (salt)
NS	-	Not significant
NSLAB	-	Non-starter Lactic Acid Bacteria
O_2	-	Oxygen
PCA	-	Principal Component Analysis
PG	-	Propylene Glycol
ppb	-	Parts per billion
ppm	-	Parts per million
P-value	-	The *p*-value is defined as the probability, calculated under the null hypothesis, of obtaining a value of the statistic that is as extreme as the one observed from the data (in a given direction) (http://www.xlstat.com, 2007)
QDA	-	Quantitative Data Analysis
S	-	Sulphur
SA	-	South Africa
spp	-	Multiple species
UHT	-	Ultra High Temperature
USA	-	United States of America
y	-	Year
y̰	-	Gamma
ZAR	-	South African Rand
α	-	Alpha
β	-	Beta
δ	-	Delta
E	-	Epsilon
ζ	-	Zeta
κ	-	Kappa
λ	-	Lambda

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

This thesis identifies the sensory characteristics that drive consumer acceptance of Cheddar cheese. In addition, optimised Cheddar cheese sensory characteristics are detailed to ensure greater consumer acceptance and thus increased consumption of Cheddar cheese.

The South African dairy industry generated revenues of ZAR 16.8 billion during 2010. Sales of hard and semi hard cheese contributed 17.5% (ZAR 2.94 billion) to the total revenue (MarketLine, 2012). Cheese production reached 39 000 metric tons of hard and semi-hard cheese during 2010 (LactoData, 2011). Cheese exports in 2010 amounted to 2 083 tons (Milk SA, 2011) at an average value of ZAR 36.78 per kilogram (Morokolo, 2011) and imported cheese to 6 331 tons (Milk SA, 2011) at an average value of ZAR 38.63 per kilogram (Morokolo, 2011).

Cheddar cheese is appreciated across a wide age, ethnic and LSM range (Milk SA, 2011) and remains a popular choice for many South African consumers (Cheese SA, 2011). Despite a growing demand for speciality and pizza cheese, approximately 84% of cheese consumers regularly eat Cheddar cheese (Cheese SA, 2011). As a result per capita consumption of cheese has doubled in South Africa to 1.9 kg in the last decade. Nevertheless, South African consumption falls below that of European countries such as France where per capita consumption is approximately 25 kg per annum (Cheese SA, 2011).

Product optimisation is the aim of every food manufacturer. There is a distinct advantage and ensured profitability for a company that can consistently optimise a product to satisfy consumer sensory requirements (McEwan, 1996; Murray and Delahunty, 2000a). Recognising the influence of cheese flavour on consumer acceptance and determining the point at which consumer acceptance would be greatest poses a challenge to Cheddar cheese marketers (Stone and Sidel, 1993; Lawless and Heymann, 2010). Equally so, recognising those production or maturation variables which may be altered to modify Cheddar flavour to ensure greater consumer acceptance pose a challenge to Cheddar cheese producers (Lawless and Heymann, 2010). Optimising the flavour of Cheddar cheese to improve consumer acceptance and consumption requires a combination of sensory and consumer analysis techniques. These two methodologies

complement one another to maximise available information in identifying those sensory aspects of the cheese that satisfy consumer requirements.

Grading and judging are traditionally used in the dairy industry to evaluate the sensory properties of cheese (Delahunty and Drake, 2004; Drake, Yates, Gerard, Delahunty, Sheehan, Turnbull and Dodds, 2005; Muir, 2010). A quality score is attained through the addition of separate values for flavour/body/texture/colour and appearance and is based on the subjective opinion of one person rather than being specifically defined (Drake *et al.,* 2005). Although suitable for quality control and measuring the reliability of production, the cheese quality score does not necessarily reflect or correlate with consumer acceptance (McBride, 1979). Furthermore, McBride (1979) suggested that assigning a single numerical grade to a Cheddar cheese is of dubious value as there appears to be no systematic relationship between grade and flavour type. Muir (2010) proposes that in order to optimise Cheddar cheese for greater consumer acceptance, a more informative grading system should be considered. In particular, the grading system should be based on positive attributes and characterise consumer demands and preferences (Muir, 2010).

Preference mapping techniques assist in determining those sensory characteristics that drive consumer acceptance. Lawless and Heymann (2010) confirm that preference mapping provides valuable information about each consumer's acceptance in a visual format. Preference mapping provides an image of the association between a product, its sensory attributes and consumer preferences (Murray and Delahunty, 2000a; Murray and Delahunty, 2000b; Young, Drake, Lopetcharat and McDaniel, 2004; Caspia, Coggins, Schilling, Yoon and White, 2006). The method requires an objective characterisation of a products sensory attributes, achieved by descriptive sensory analysis (DSA) , which is then related to preference ratings for the product obtained from a representative sample of consumers (Murray and Delahunty, 2000a).

Partial least squares regression (PLS) has been used in a number of studies to determine the drivers of consumer liking. In this multivariate technique, the dependent (*y*) variables in the PLS model are the overall liking ratings of the consumers and the independent (*x)* variables are the sensory attribute ratings. Since PLS can handle multiple dependent variables in the same model, the overall liking ratings of the total respondent base, as well as those of any consumer segments of interest, can be fit in a single analysis. This is helpful for determining the similarities and the differences in the attributes that drive liking among the segments (Meilgaard, Civille and Carr, 2007).

Limited research has been published utilising preference mapping techniques to understand consumer perception and acceptability of the flavour profiles of Cheddar cheese. Cheddar cheese is a dynamic product (Fox and McSweeney, 2004) which is considered marketable at any time between two and twelve months of ripening (Green and Manning, 1982). The wide range of acceptable flavour characteristics within this cheese category make it difficult to provide one

definition for Cheddar cheese flavour that satisfies the sensory requirements for all Cheddar cheese consumers (Fox, Guinee, Cogan and McSweeney, 2000). Cheddar cheese characteristically develops from mild flavours of creamy, buttery and cooked milk to the more complex aged flavours of fruity, brothy, nutty and catty as it matures (Piggott and Mowat, 1991; Drake, McIngvale, Gerard, Cadwallader and Civille, 2001).

2. THE RESEARCH QUESTION

The aim of this research was to explore the influence of flavour and texture on consumer acceptance of Cheddar cheese. If Cheddar cheese producers and marketers have insight into the drivers of consumer acceptance for Cheddar cheese, then the sensory characteristics of Cheddar cheese can be optimised to ensure greater consumer sensory satisfaction and thus increased consumption.

In broad terms this study determined the association between six cheese samples, their sensory attributes, instrumental attributes and consumer preferences.

A comprehensive Literature review is presented in Chapter 2. Cheddar cheese flavour is discussed and conceptualised. Reference is made to the cheese's history, how it is produced and the biochemical pathways that contribute to flavour and texture development. Consumer trends within the market are outlined and the nutritional value of cheese summarised. Finally sensory analysis is discussed with specific reference to descriptive sensory analysis of Cheddar cheese and preference mapping techniques employed to characterise Cheddar cheese flavour and consumer acceptance.

Chapter 3 examines the results of descriptive sensory analysis conducted on the six cheese samples. The cheese samples are characterised and differentiated by appearance, aroma, flavour and textural attributes. In addition the effect of cheese maturation on the sensory attributes is outlined.

Chapter 4 discusses results of the instrumental colour analysis conducted on the six cheese samples.

Chapter 5 examines the results of two focus group sessions conducted to explore and gain a greater understanding of consumer attitudes towards cheese. Consumer opinions on the six cheese samples are also investigated.

Chapter 6 details the results of the consumer acceptance of the six cheese samples. Hedonic data for the overall liking of the six cheeses together with demographic and attitudinal data is collected via a consumer panel consisting of 115 participants. Data are subjected to partial least squares analysis to establish a greater understanding of the descriptive sensory attributes and colour measurements that influence consumer preference and thus examine the relationship between

descriptive sensory analysis and consumer liking of a cheese. Hierarchical cluster analysis is also performed on the data to determine clusters of consumers with similar acceptance behaviour. Analysis of variance is conducted on each of the variables separately (colour, texture, flavour and overall liking). The results provide detailed information on the consumer preference per cluster.

Rather than looking at demographics and then at levels of consumer acceptance, PLS regression offers an alternative way of examining consumer acceptance. PLS is performed on each cluster in an attempt to relate the clusters to the demographic and attitudinal data. Consequently consumer acceptance is identified and based on these results, demographic and attitudinal behaviour are further investigated to define the clusters more specifically. As a result, areas where Cheddar cheese can be optimised to satisfy specific consumer sensory requirements are identified.

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CHAPTER 2

LITERATURE REVIEW: A SENSORY APPROACH TO CHEDDAR CHEESE

1. INTRODUCTION

Flavour is a crucial component of consumer acceptability (Dacremont and Vickers, 1994). Furthermore, to succeed in the market place, the sensory profile of a product should meet or exceed a consumer's expectation (Muir, 2010). Understanding the influence of cheese flavour on consumer acceptance and determining the point at which consumer acceptance would be greatest poses a challenge to Cheddar cheese marketers (Stone and Sidel, 1993; Lawless and Heymann, 2010). Equally so, recognising those production or maturation variables which may be altered to modify Cheddar flavour to ensure ultimate consumer acceptance pose a challenge to Cheddar cheese producers (Lawless and Heymann, 2010).

Since Cheddar cheese is a biochemically dynamic product (Fox and McSweeney, 2004), no two batches of the same variety are ever expected to be identical in flavour (Fox and McSweeney, 2004). In addition, Cheddar cheese is considered marketable at any time between two and twelve months of ripening (Green and Manning, 1982).The wide range of acceptable flavour and texture characteristics within the category make it difficult to define Cheddar cheese flavour (Fox, Guinee, Cogan and McSweeney, 2000) in terms of sensory quality (Delahunty and Drake, 2004).

Lexicons exist and accurately describe the flavour characteristics of Cheddar cheese (Heisserer and Chambers, 1993; Murray and Delahunty, 2000a; Drake, McIngvale, Gerard, Cadwallader, and Civille, 2001; Drake, Gerard, Wright, Cadwallader, and Civille, 2002). It is, however, important to understand the Cheddar cheese flavours that drive consumer acceptance in the South African context. Since Lawless and Heymann (2010) suggest that the best models to provide information on how consumers are likely to react to and perceive food products are based on human sensory data, it would be prudent to conduct both analytical (using trained descriptive panels) and affective sensory analysis (using the target consumer) of Cheddar cheese in South Africa. In addition, Piggott (2000) explains that flavour is an interaction of food and consumer. A study of flavour is subsequently incomplete unless consumer considerations together with the physical and chemical aspects of food are taken into account.

The purpose of this literature review is threefold. Firstly, Cheddar cheese flavour is discussed and conceptualised. Reference is made to the cheese's history and how it is produced and the

biochemical pathways that contribute to flavour and texture development are explained. Following this, the literature review examines consumer trends within the cheese market and outlines the nutritional value of Cheddar cheese. Finally, sensory analysis is discussed, with specific reference to descriptive sensory analysis and preference mapping techniques employed to characterise Cheddar cheese flavour and consumer acceptance.

2. THE SENSORY CHARACTER OF CHEDDAR CHEESE

Flavour perception *per se,* is a highly complex (Walstra, Wouters and Geurts, 2006). It is an integrated system that combines stimuli from aroma receptors in the nasal cavity with those stimuli perceived from the taste and trigeminal receptors in the mouth (Delahunty and Drake, 2004; Lawless and Heymann, 2010). Flavour perception occurs prior to and during consumption (Delahunty and Drake, 2004) and often the flavour and aroma of a product are not easily distinguished from one another (Robinson and Wilbey, 1998).

Cheddar cheese flavour, experts agree, is complex, variable and difficult to conceptualise (Aston and Dulley, 1982; Fox *et al.,* 2000; O'Riordan and Delahunty, 2003). Joseph Harding, in 1864 described the ideal quality of Somerset Cheddar as close and firm in texture, yet mellow in character or quality, rich with a tendency to melt in the mouth, the flavour full and fine approaching that of a hazelnut (Transactions of the New York State Agricultural Society, 1865). Further attempts to describe Cheddar flavour lead to the Component Balance Theory proposed by Mulder (Mulder, 1952). The theory suggests that cheese flavour is the result of the correct balance and concentration of flavour rendering compounds. An excess or deficiency of any one of the compounds produced from the microbiological, chemical and biochemical reactions that take place during cheese ripening (McSweeney, 2004) may lead to atypical flavour development (Mulder, 1952).

2.1 Cheddar cheese aroma

Cheddar cheese aroma arises mainly from the volatile components released by the curd as ripening proceeds (Robinson and Wilbey, 1998; Fox *et al.*, 2000) and is normally the first aspect of flavour encountered (Delahunty and Drake, 2004). The volatile stimuli are delivered to the nose orthonasally by sniffing or released into the buccal cavity air during consumption and thus delivered to the nose retronasally (Delahunty and Drake, 2004; Lawless and Heymann, 2010).

Many hundreds of different volatile compounds, each with distinctive aroma character have been identified in cheese and these provide the largest contribution to the diversity of cheese aroma (Singh, Drake, and Cadwallader, 2003; Delahunty and Drake, 2004). Table 1 lists the aroma compounds identified in Cheddar cheese in various studies. Dacremont and Vickers

(1994) suggested that Cheddar cheese aroma is sensory concept, and not made up of any one odour, but rather a range of different odourants which share more similarities together than do odours of other types of cheese. It must be noted, however, that aroma alone provides an incomplete assessment of Cheddar cheese flavour (Muir, Banks and Hunter, 1997).

In attempting to define Cheddar aroma, Dacremont and Vickers (1994) proposed that a recognizable Cheddar cheese aroma could be produced by a mixture of 2,3-butanedione, methional and butyric acid. Zehentbauer and Reineccius (2002), however, suggested that 2,3-butadione (buttery), (Z)-4-hepenal (creamy), methional (potato-like), 2-acetyl-1-pyrroline (roasted), dimethyl trisulphide (cabbage), 1-octen-3-one (mushroom), (*Z*)-1,5-octadien-3-one (green), furaneol (caramel), (*Z*)-2-nonenal (green) and (*E*)-2-nonenal aroma compounds were responsible for the odour of Cheddar cheese. Cadwallader, Drake, Carunchia-Whetstine and Singh (2006) reported that the broth-like flavour notes identified in Cheddar cheese were as a result of methional, furaneol and 2-methyl-3-furanthiol (MFT).

2.2 Cheddar cheese flavour

Cheddar cheese flavour is the result of the biochemical breakdown of milk proteins, milk fat, lactose and citrate by enzymes in the milk (plasmin and lipase), enzymes added to the milk (chymosin and rennet) and enzymes secreted by micro-organisms or released by microbial cells following cell death and lysis (Urbach, 1993; Fox *et al.,* 2000). The final targeted flavour profile of ripened Cheddar cheese, however, is variable and defined by the different end consumer requirements and traditional cultural flavour expectations.

Cheese flavour is specific to country, ethnicity and end application (Lawrence, Gilles, Creamer, Crow, Heap, Honoré, Johnston and Samal, 2004; Drake, Yates, Gerard, Delahunty, Sheehan, Turnbull and Dodds, 2005). Despite the many compounds (Dacremont and Vickers 1994, Milo and Reineccius, 1997; Zehentbauer and Reineccius, 2002) that have been isolated from Cheddar cheese, no synthetic mixture has been formulated which fully recreates Cheddar cheese flavour (Urbach, 1993; Singh *et al.,* 2003). Sensory analysis, suggests Le Quéré (2004), is clearly a valid means to measure Cheddar cheese flavour characteristics. Chemesthesis, also an aspect of flavour, is a term used to describe the sensory system responsible for detecting chemical irritants (Delahunty and Drake, 2004; Lawless and Heymann, 2010). With regard to Cheddar cheese, the pungency and prickle or bite of a mature Cheddar cheese are examples of perceived chemical irritation (Delahunty and Drake, 2004).

Table 1 Aroma compounds identified in Cheddar cheese in various studies. Compounds are listed in the order of their importance in odour.

Mild Cheddar[a]	Mild Cheddar[b]	Mature British Farmhouse Cheddar [c]
Homofuraneol	Furaneol	2-Isopropyl-3-methoxypyrazine
Butyric acid	(E)-2-Nonenal	3-(Methylthio) propanal
Furaneol	2,3-Butanedione	p-Cresol
δ-Decalactone	(Z)-4-Heptenal	δ-Dodecalactone
Skatole	3-(Methylthio) propanal	Butanoic acid
6-(Z)-Dodecenyl-γ-lactone	1-Octen-3-one	Isovaleric acid
3-(Methylthio) propanal	2-Acetyl-2-thiazoline	2-Phenylethanol
(E)-β-Damascenone	Dimethyl trisulfide	Ethyl octanoate
2,3-Butanedione	(Z)-1,5-Octadien-3-one	Acetic acid
Nonanal	(Z)-2-Nonenal	β -Damascenone
trans-4,5-Epoxy-2(E)-decenal	Ethyl butanoate	Octanoic acid
Aceticacid	Hexanal	4,5-Dimethyl-3-hydroxy-2(*5H*)-furanone
(E)-2-Nonenal	2-Isobutyl-3-methoxypyrazine	(sotolon)
δ-Dodecalactone	*trans*-4,5-Epoxy-2-(E)-decenal	Phenyl acetic acid
1-Octen-3-one	2-Nonanone	Ethyl butanoate
(Z)-2-Nonenal	2-Isopropyl-3-methoxypyrazine	Ethyl hexanoate
2-Acetylthiazoline	Decanal	Dimethyl trisulfide
	2/3-Methyl butanal	Phenyl acetaldehyde
	Ethyl octanoate	Pentanoic acid
	1-Hexen-3-one	Guaiacol
	Methyl propanal	γ-Decalactone
	Ethyl hexanoate	δ-Decalactone
	Homofuraneol	1-Octen-3-one
	Butyric acid	2-Acetylpyrazine
		2-Isobutyl-3-methoxypyrazine
		Linalool
		(E,Z)-2,6-Nonadienal
		Geosmin
		Furaneol

[a] Diethyl ether extract of mild Cheddar cheese analysed by GCO/AEDA/GC-MS (Milo and Reineccius, 1997)

[b] Mild Cheddar cheese analysed by GCO/AEDA/GC-MS and GCO-H/DHDA/GC-MS (Zehentbauer and Reineccius, 2002)

[c] Diethyl ether extract of British Farmhouse Cheddar cheese analysed by GCO/AEDA/GC-MS (Suriyaphan, Drake, Chen and Cadwallader, 2001)

2.3 Cheddar cheese taste

The taste of Cheddar cheese arises from a mixture of water soluble, non-volatile compounds believed to be the products of proteolysis (Fox *et al.*, 2000). As the primary stimuli for taste, these non-volatile compounds must come into contact with the taste receptors on the tongue and soft palate. This contact creates perceptions that provide the distinctive taste qualities of sweet, salty, sour/acid, bitter and umami (Delahunty and Drake, 2004). The principal acid in cheese is lactic acid (Delahunty and Drake, 2004). The concentration of lactic acid is influenced by the starter culture, the extent to which the lactic acid is lost in the whey and its metabolism by secondary micro-flora in the cheese. Acetic, proprionic and butyric acids may also contribute to acidity, however, their contribution principally affects cheese aroma (Fox *et al.*, 2000). Salty taste is stimulated by small inorganic ions; however, the compound responsible for salty taste is NaCl, which is added during Cheddar cheese manufacture (McSweeney, 1997). Free amino acids and peptides contribute to sweet, bitter and umami tastes (Delahunty and Drake, 2004). Methionine, histidine, lysine, tryptophan, leucine, isoleucine, agrinine, phenylalanine and tyramine amino acids have bitter tastes; serine, glycine, alanine, hydroxyproline, proline, aminobutyric acid, valine and threonine amino acids have sweet tastes, while aspartic acid and glutamic acid have broth-like flavours (Robinson and Wilbey, 1998).

3. THE SOUTH AFRICAN DAIRY INDUSTRY

The South African dairy industry generated revenues of ZAR 16.8 during 2010 to achieve a compound annual growth rate of 5% for the period 2006 – 2010 (Market Line, 2012). The industry is comprised of two sectors; the primary, which produces milk and the secondary which processes the milk (Lacto Data, 2011). A total of 2.6 billion litres of milk was supplied to the market in 2010 of which 60% was directed to liquid milk products and 40% to concentrated products (Lacto Data, 2011). Liquid products include pasteurised milk, UHT and sterilised milk, yoghurt, maas, buttermilk and flavoured milk. Concentrated products include hard and semi-hard cheese, other cheese, milk powders, butter, whey powder, buttermilk powder and condensed milk. Milk sales produced the most profitable results, generating revenues of ZAR 9.49 billion in 2010, while cheese sales generated ZAR 2.94 billion for the same period (Market Line, 2012).

Cheddar cheese remains the most popular cheese in South Africa and holds a 31.9% market share of the everyday cheese sector, followed by Mozzarella at 22.8% and Gouda at 20.8% (BMI, 2011). It is believed that 84% of all South African cheese consumers eat Cheddar cheese (Cheese SA, 2011). In the period up to 2010, Cheese SA (2011) reported an increase in per capita consumption of cheese from 1 kg to approximately 1.9 kg, indicating a greater

awareness, availability and access to cheese. This increase in consumption, Cheese SA (2011) further explains has been driven by promotional campaigns encouraging increased dairy intake for nutritional benefits. Future consumption trends will depend largely on the development of a South African consumer middleclass. An improvement in the economic situation of any population according to Cheese SA (2011) will undoubtedly result in an increase in consumption of cheese and thus greater demand for the product.

4. CHEDDAR CHEESE

Originating in the village of Cheddar in Somerset, South West England, during the 1500's, Cheddar cheese is possibly one of the oldest and most important cheese varieties made worldwide (Fox and McSweeney, 2004). Defined as a firm bodied cheese that is produced by subjecting milk, non-fat milk, or cream to the action of a lactic acid producing bacteria culture and clotting enzyme (rennet). It contains not more than 39% moisture by weight and not less than 50% milk fat by weight of the solids (Igoe, 2011). Cheddar cheese is further defined as a hard, close textured bacteria ripened cheese that requires several months aging to develop its characteristic flavour (Robinson and Wilbey, 1998; Law, 2010).

It is the process of cheddaring during cheese manufacture that distinguishes this cheese from other types (Law, 2010; Walstra *et al.*, 2006). Described as the piling and repiling of warm curds on top of one another, the cheddaring process places curds under gentle pressure to assist in whey drainage. At the same time, curd granules fuse and the texture of the curd mass becomes rubbery and pliable (McSweeney, 2004). The process allows for further lactic acid production which contributes to the destruction of coliform bacteria (Kosikowski, 1978).

5. CHEDDAR CHEESE MANUFACTURE

Cheddar cheese making has been extensively studied and reviewed (Kosikowski, 1978; Robinson and Wilbey, 1998; Singh *et al.,* 2003; Fox and McSweeney 2004; Law, 2010). Experts agree, however, that the process can be outlined by two distinct phases. During the first phase, normally complete within 24 hours, milk is converted to a curd. This is followed by the second phase where the curd is ripened from between two and 48 months (Singh *et al.*, 2003; Fox and McSweeney, 2004). Figure 1 details the processes involved during the manufacture of Cheddar cheese.

Singh *et al.* (2003) suggest that while the unique characteristics of cheese flavour, aroma and texture develop during ripening, it is the compositional factors of moisture, salt, pH and starter

type, determined during the manufacturing process that lay the foundation for these biochemical changes.

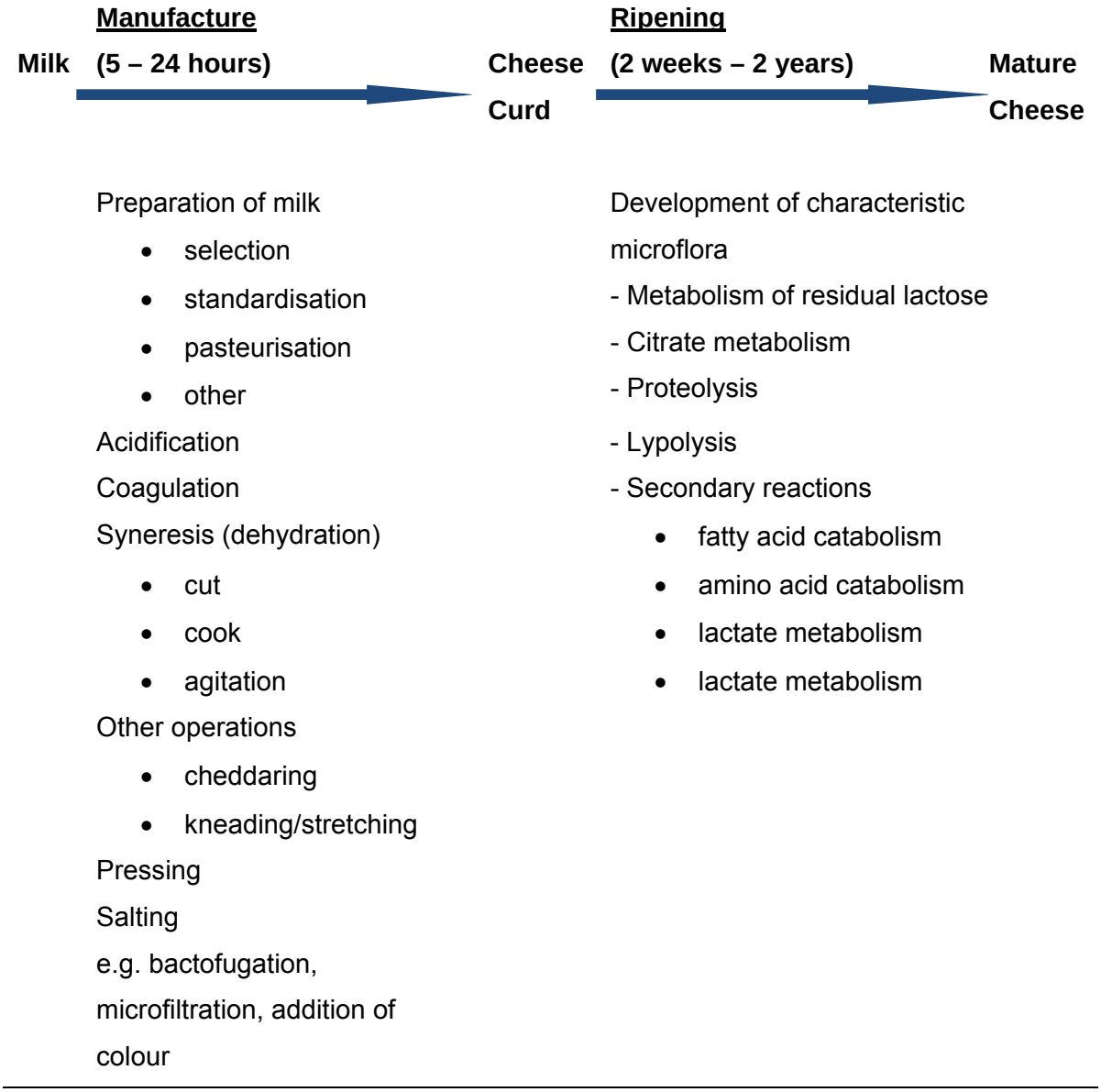


Figure 1 General description of Cheddar cheese manufacture (Fox and McSweeney, 2004; Singh *et al.,* 2003).

The production of Cheddar cheese can be summarised as follows:

5.1 Milk Selection and Standardisation

Milk of high microbial and chemical quality is selected and standardised by skimming some of the cream off the milk. This process compensates for seasonal variations and enables the producer to adjust for different fat requirements of the cheese. The milk is standardised in terms of the casein to fat content, typically to a 0.70:1 ratio. Walstra *et al.* (2006) suggests that changing the ratio between fat and fat-free dry matter in cheese milk affects clotting and syneresis and hence water content and pH of the cheese. Furthermore, flavour and consistency are linked to the fat content in the dry matter. The milk is then heat treated to eliminate the presence of undesirable bacteria (Robinson and Wilbey, 1998; Walstra *et al.,* 2006; Johnson and Law, 2010).

5.2 Acidification

Acidification commences with inoculation of the milk with the starter culture. The cultures, containing lactic acid bacteria, ferment the milk lactose to lactic acid which results in a lowering of the pH (Singh *et al.,* 2003, Walstra *et al.,* 2006). As the pH drops, the functionality and the rate of enzyme activity by the coagulant increases and contributes to syneresis of the curd (Walstra *et al.,* 2006; Johnson and Law, 2010). The starter culture continues to ferment lactose until conditions such as salt, pH and temperature within the cheese prevent it from doing so (Johnson and Law, 2010). The enzymes involved in the formation of aroma and flavour compounds are predominantly derived from the starter culture (Walstra *et al.,* 2006). Starter cultures generally inoculated into the milk for Cheddar cheese include *Lactococcus lactis* subsp. *lactis* and/or *Lc. lactis* subsp. *cremoris*, *Streptococcus thermophilus* and a *Lactobacillus* spp. (*Lb. delbruekii* subsp. *bulgaricus, Lb. delbruekii* subsp. *casei, Lb delbruekii* subsp. *lactis* or *Lb. helveticus* (Robinson and Wilbey, 1998; Marilley and Casey, 2004).

5.3 Coagulation

Coagulation of the milk by rennet is a two-step process (Singh *et al.,* 2003). During the first phase, which occurs independently of temperature, the κ-Casein is enzymatically hydrolysed to para-κ-casein (Robinson and Wilbey, 1998; Singh *et al.,* 2003; Johnson and Law, 2010). Once approximately 90% of the κ-casein has been converted to para-κ-casein and in the presence of sufficient calcium ions and temperatures greater than 20°C (Singh *et al.,* 2003), the casein micelles combine to form a coagulum which encloses the remainder of the milk components (Robinson and Wilbey, 1998; Johnson and Law, 2010). During coagulation, lactic acid continues to develop (Robinson and Wilbey, 1998; Singh *et al.,* 2003; Johnson and Law, 2010).

Approximately 6% of the rennet remains in the cheese curd where it is still active (Johnson and Law, 2010).

5.4 Cutting the coagulum

Cutting the coagulum increases the curd surface area which ensures effective whey expulsion and permits the resulting equal sized curds to be cooked uniformly throughout (Johnson and Law, 2010). The rate and extent of syneresis depends on the size of the curd grains and on the intensity and duration of the stirring of the curd-whey mixture (Walstra *et al.,* 2006). The finer the coagulum is cut, the greater the surface area exposed and the more fat is lost (Johnson and Law, 2010). Whey from the cut curds carries water soluble components such as lactose, whey proteins, salts, peptides and other nitrogenous substances (Robinson and Wilbey, 1998; Johnson and Law, 2010).

5.5 Stirring and scalding

The introduction of heat through the cut curds and whey for a specific time is generally accompanied by agitation and continuous heating (Kosikowski, 1978). The objective of this step is to contract the curd particles and drive out free whey. This influences curd texture, allows time for lactic acid development, arrests it and finally plays a role in the final cheese moisture level (Walstra *et al.,* 2006). The curd, when first cut, is soft and the coat surrounding the particles is open. Stirring the curd gently until the first flush of whey has left the curd particles is necessary to prevent undue crushing and loss of fat. Once the curd coat becomes more membrane like, the rate of stirring can be increased (Johnson and Law, 2010). Scalding promotes contraction of the protein matrix, causing the curd to shrink and expel more whey (Singh *et al*., 2003). The increase in temperature speeds up the metabolism of the lactic acid bacteria within the curds. As lactic acid increases, the pH continues to decline. The acidity assists in shrinking the curd particles to express more whey (Johnson and Law, 2010).

5.6 Draining, cheddaring and milling

Draining separates the whey from the curds and allows time for the curds to coalesce and for additional lactic acid development (Kosikowski, 1978). As whey is drained from the vat, the curd is allowed to mat together. The mat is then cut into slabs which are turned and piled on top of one another in a process called “cheddaring” (Johnson and Law, 2010). This unique step of piling and repiling of the warm curd in the cheese vat continues for approximately 2 hours (Kosikowski, 1978). During this time, lactic acid continues to develop and the curd structure flattens and acquires a fibrous texture (Kosikowski, 1978; Johnson and Law, 2010). The curd is then cut into thumb sized or smaller pieces called “curd chips” (Walstra *et al.*, 2006;

Law, 2010). Shredding or milling takes place to reduce the size of the curd blocks to a size suitable for salting (Johnson and Law, 2010).

5.7 Salting

Essential for a good cheese (Singh *et al.*, 2003; Johnson and Law, 2010), dry salt is generally mixed with the curd and allowed to "mellow" for approximately 10 minutes (Walstra *et al.,* 2006). Salt not only influences flavour, but promotes further curd syneresis which in turn regulates curd moisture; it influences the activity of the rennet, lactic acid bacteria and non-starter lactic acid bacteria (NSLAB), their enzymes and the indigenous milk enzymes (Kosikowski, 1978; Singh *et al.*, 2003).

5.8 Moulding and pressing

The process of moulding or pressing shapes the loose curd particles into a form that is compact enough to be handled and to expel any free whey (Kosikowski, 1978; Johnson and Law, 2010).

5.9 Ripening

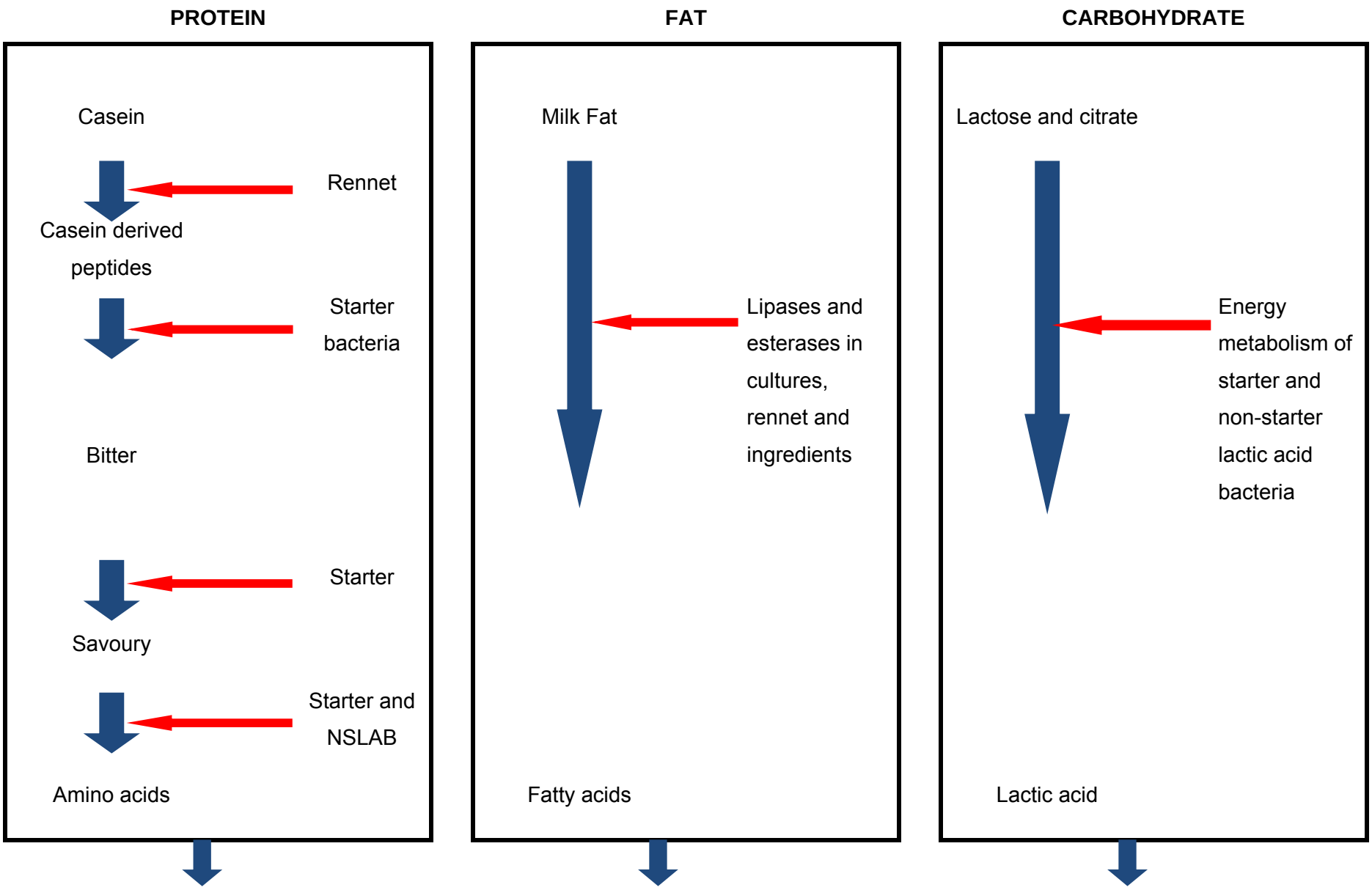
The shaped cheese is ripened under controlled temperature of between 8°C and 12°C (Singh *et al.,* 2003) and humidity (Kosikowski, 1978) for between two and 48 months (Kosikowski, 1978; Singh *et al.*, 2003; Johnson and Law, 2010;). The ripening period provides the microorganisms and enzymes in the cheese with an opportunity to hydrolyse the fat, protein, lactose and other compounds for the characteristic flavour, aroma and texture development of a Cheddar cheese (Kosikowski, 1978; Singh *et al.,* 2003; Johnson and Law, 2010).

6. CHEDDAR CHEESE FLAVOUR AND TEXTURE DEVELOPMENT

Flavour development in Cheddar cheese results from a slow and controlled decomposition of the rennet-induced coagulum (Upadhyay, McSweeney, Magboul, and Fox, 2004). It is the direct consequence of the biochemical activities of proteolysis, lipolysis and the metabolism of residual lactose, lactate and citrate that produce flavour rendering compounds (McSweeney, 1997; Upadhyay *et al.*, 2004). Figure 2 details the biochemical events in the conversion of protein, fat and carbohydrate in cheese to flavour compounds. Table 2 outlines those flavour compounds generated during the ripening process.

Table 2 Flavour compounds generated from the three principal milk constituents during cheese ripening (Sing *et al.,* 2003).

Casein	**Milk fat**	**Lactose and citrate**
Peptides	Fatty acids	Lactate
Amino acids	Keto acids	Pyruvate
Acetic acid	Methyl ketones	CO_2
Ammonia	Lactones	Diacetyl
Pyruvate		Acetoin
Aldehydes		2,3-butandiol
Alcohols		Acetaldehyde
Carboxylic acid		Acetic acid
Sulphur compounds		Ethanol


PROTEIN
Casein
Rennet
Casein derived peptides
Starter bacteria
Bitter
Starter
Savoury
Starter and NSLAB
Amino acids
FAT
Milk Fat
Lipases and esterases in cultures, rennet and ingredients
Fatty acids
CARBOHYDRATE
Lactose and citrate
Energy metabolism of starter and non-starter lactic acid bacteria
Lactic acid

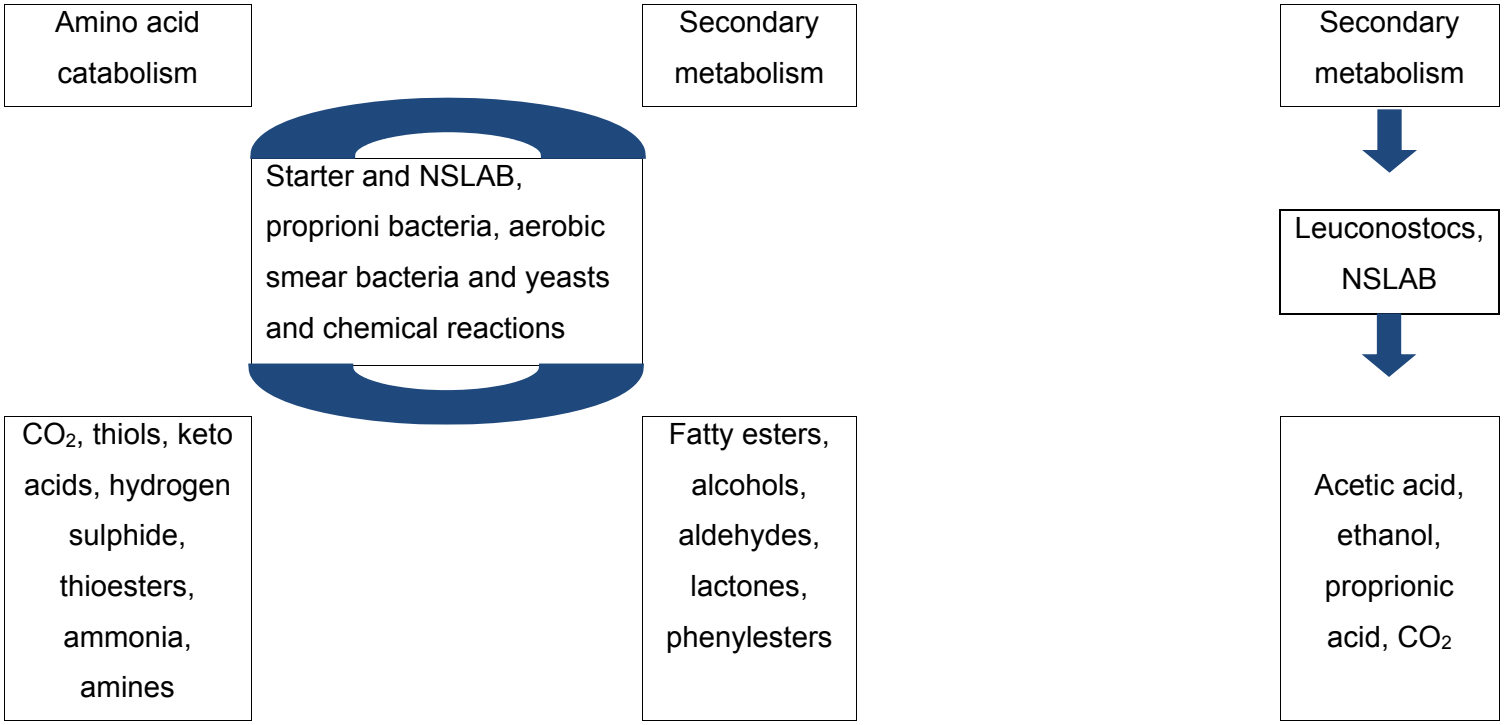


Figure 2 Basic cheese ripening technology. The known biochemical events in the conversion of protein, fat and carbohydrate in cheese to flavour compounds (Law, 2010).

6.1 Proteolysis

Undoubtedly the most complex biochemical pathway, proteolysis contributes directly to flavour development through the formation of peptides and free amino acids necessary for further catabolism during ripening (McSweeney, 1997; Walstra *et al*., 2006). Proteolysis is mediated by proteinases and peptidases from five sources (McSweeney and Fox, 1997; Upadhyay *et al*., 2004) listed below:

- The coagulant is a principal agent for the initial hydrolysis of caseins during ripening. In the development of flavour compounds, it is the κ-casein that is initially cleaved by the rennet enzymes to destabilise the casein micelle to form a weak gel (Law, 2010). The rennet is trapped in the curd matrix and its action continues throughout the ripening process, inducing mainly the release of large molecular weight peptides (Adda, Gripon and Vassal, 1982). These peptides are the precursors for free amino acids which together with their degradation products are important flavour compounds (McSweeney and Fox, 1997). Casein derived peptides are either tasteless or bitter and do not contribute directly to the taste or flavour of the cheese, however, they play an important role in texture development (Law, 2010).
- Indigenous milk enzymes such as plasmin, an alkaline milk proteinase, also hydrolyses casein, particularly β-casein.
- Lactic acid bacteria (LAB). The cell envelope proteinases (CEP) and intracellular enzymes of the starter cultures hydrolyse the intermediate sized peptides into short peptides which are further degraded by a range of intracellular peptidases to free amino acids (McSweeney and Fox, 1997).
- Non-starter Lactic acid bacteria (NSLAB).
- Adjunct starter micro-organisms.

The free amino acids form a pool from which other components of flavour or aroma are formed. Amino acids have a distinct sensory attributes which Robinson and Wilbey (1998) describe as:

- Bitter – methionine, histadine, lysine, tryptophan, leucine, isoleucine, arginine, phenylalanine and tyramine.
- Sweet – serine, glycine, alanine, gydroxyproline, proline, aminobutyric acid, valine and threonine.
- Broth-like – aspartic acid and glutamic acid.
- Rubber-like – cystine.

- Little or no flavour– asparagines, glutamine and tyrosine.

McSweeney and Fox (1997) suggest that the main contribution of proteolysis to cheese flavour is the production of precursors for a range of poorly understood reactions involving the catabolism of free amino acids. Decarboxylation, deamination, transamination or other transformations of amino acids and/or their side chains result in the formation of a wide range of volatile flavour compounds. These include phenylacetic acid, phenethanol, ρ-cresol, methane thiol, dimethyl disulphide, 3-methyl butyrate, 3-methyl butanal, 3-methyl butaniol, 3-methyl-2-butanone, 2-methyl propionate, 2-methyl-1-propanal, 2-methyl butyrate and 2-methyl butanal phenyacetic acid (Marilley and Casey, 2004). Table 3 lists the amino acid catabolites formed by the lactic acid bacteria in Cheddar cheese.

Table 3 Amino acid catabolites formed by lactic acid bacteria isolated from Cheddar cheese (Singh *et al.*, 2003, Marilley and Casey, 2004).

Catabolic products	Precursor	Aroma note
2-Methyl propanoic acid	Valine	Rancid, butter, sweaty, sweet, apple-like
2-Methyl-1-propanol	Valine	Penetrating, alcohol, wine-like
2-Methyl propanal	Valine	Malt
3-Methyl butanoic acid	Leucine	Cheesy, sweaty, old socks, rancid, faecal, rotten fruit
3-Methyl-1-butanol	Leucine	Fruity, alcohol, solvent-like, grainy
3-Methyl butanal	Leucine	Dark chocolate, malt
2-Methyl butanoic acid	Isoleucine	Fruity, waxy, sweaty-fatty acid
2-Methyl-1-butanol	Isoleucine	-
2-Methyl butanal	Isoleucine	Dark chocolate, malt
3-(Methylthio) propanal	Methionine	Cooked/boiled potato
3-(Methyylthio) propanol	Methionine	Cooked/boiled potato
Methanethiol	Methionine/cysteine	Cabbage, boiled cabbage, sulphurous
Methyl sulphide	S-containing	Cabbage, sulphurous
Dimethyldisulfide	S-containing	Onion
Dimethyltrisulfide	S-containing	Garlic

Dimethyltetrasulfide	S-containing	Cabbage
Acetophenone	Phenylalanine	Almond, musty, glue
Benzaldehyde	Phenylalanine	Almond, bitter almond
Phenyl acetaldehyde	Phenylalanine	Rosy, violet-like
Phenylethyl alcohol	Phenylalanine	Unclean, rose, violet-like, honey
Phenyl acetic acid	Phenylalanine	Flowery, rosy, plastic
Phenol	Tyrosine	Medicinal
p-OH-phenyl aldehyde	Tyrosine	-
p-OH-phenyl lactate	Tyrosine	-
p-OH-phenyl acetate	Tyrosine	-
p-Cresol	Tyrosine	Unclean, medicinal
Indole	Tryptophan	Unclean, mothball
Skatole	Tryptophan	Unclean, mothball
Benzaldehyde	Tryptophan	Almond

6.2 Lipolysis

Although considered a high fat product (Singh *et al.*, 2003), evidence suggests that lipolysis in Cheddar cheese is limited (McSweeney and Fox, 1997; Singh *et al.,* 2003). Robinson and Wilbey (1998) suggest that only at levels above 0.2%, can C_4-C_{18} fatty acids give rise to unacceptable, rancid flavours. Nevertheless, the function of the fat remains an important one of dissolving and holding flavour components (Singh *et al.*, 2003). The lypolytic enzymes, esterases and lipases mediate lipolysis and hydrolyse the triglycerides to mono– and diglycerides and ultimately to free fatty acids (McSweeney and Fox, 1997; Robinson and Wilbey, 1998; Singh *et al.,* 2003; Law, 2010). These enzymes originate in the cheese milk, the starter culture lactic acid bacteria (LAB) and the non-starter lactic acid bacteria (NSLAB) (Singh *et al.*, 2003). The activity, however, of the indigenous lipoprotein lipase found in the milk is reduced considerably by pasteurisation (Singh *et al.*, 2003). Flavour compounds generated from lipolysis include fatty acids, keto acids, methyl ketones, lactones and esters, alcohols, aldehydes and phenyl esters (Robinson and Wilbey, 1998; Singh *et al.*, 2003; Law, 2010).

6.3 Glycolysis and the metabolism of citrate

During the manufacture of cheese, lactose and in some cases citrate, are metabolised by the lactic acid bacteria to form lactic acid of mainly the L-isomer (Robinson and Wilbey, 1998 McSweeney, 2004; Law, 2010). In the case of Cheddar cheese, most of the lactic acid is produced in the vat prior to salting and moulding (Singh *et al.*, 2003). The cheese curd, however, may contain low levels of residual lactose, which is rapidly metabolised to lactate, either L (+) or L (-) or a mixture of the two early on in the ripening process (McSweeney, 2004; Law, 2010).

Lactate is an important substrate for a range of reactions which contribute to flavour. In most cases L-lactate is racemized to D-lactate by the NSLAB flora and in the presence of O_2, some members of the NSLAB flora, particularly pediococci, can oxidise lactate to formate and acetate (McSweeney and Fox, 1997). Lactose can be further metabolised to ethanol, butanol and acetone, as well as acids such as acetic and formic acids (Law, 2010). The relatively low levels of citrate in milk (~8 mM) belie its contribution to flavour development (McSweeney and Fox, 1997). Cheddar cheese contains only 0.2 – 0.5% (w/w) citrate, which is metabolised by *Lc. lactis* biovar. *diacetylactis* and *Leuconostoc* spp. to produce diacetyl and CO_2 (Singh *et al.*, 2003). The principal components from the metabolism of citrate affecting flavour development in cheese are acetate, diacetyl, acetoin and 2,3-butandiol (Singh *et al.*, 2003). Diacetyl is usually produced in small amounts, while acetoin is generally produced at much higher concentrations. Acetate is produced from citrate in equimolar concentrations (Singh *et al.*, 2003).

7. NUTRITIONAL VALUE

Cheese is a nutritious, versatile dairy food (O'Brien and O'Connor, 2004) with a long history in the human diet. Robinson and Wilbey (1998) report that Gorgonzola was first noted in literature in 897 AD and Cheddar around 1500 AD. Although the primary objective of cheese making is to conserve the principal ingredients of milk to prolong shelf-life (Fox and McSweeney, 2004), cheese has become a staple food in modern diets and enjoyed for its sensory eating quality (Delahunty and Drake, 2004). The nutrient composition of Cheddar cheese is listed in Table 4.

The Consumer Education Project, an initiative by Milk South Africa, was launched in 2007 to promote the health and nutritional benefits of dairy. Three servings of dairy are recommended every day to ensure optimal calcium intake and benefit from all the nutrients that dairy has to offer (Milk SA, 2011). The project promotes and describes dairy products as nutrient dense or

nutrient rich, that is, their ratio of nutrient content (in grams) is high compared with the total energy content (Milk SA, 2011).

The chemical composition of milk largely determines its nutritional value (Walstra *et al.*, 2006). Cow's milk, as the main ingredient in cheese, is recognized as an excellent source of high-quality protein as it contains, in varying amounts, all nine of the essential amino acids that human bodies cannot synthesize (Miller *et al.*, 2007). Furthermore, cow's milk contains approximately 3.5% protein by weight and contributes about 21% of the energy of whole milk (Miller *et al.,* 2007). Lactose, a disaccharide composed of glucose and galactose is the principal carbohydrate source in milk and contributes about 30% of the energy of whole milk (Miller *et al.*, 2007). The fat is largely made up of triglycerides and lipids which include phospholipids, cholesterol, free fatty acids, monoglycerides and diglcyerides (Walstra *et al.*, 2006). Miller *et al.* (2007) suggest that it is milk fat that contributes the unique characteristics to the appearance, texture, flavour and stability of dairy foods. Furthermore, milk fat is a source of energy, essential fatty acids, fat-soluble vitamins and several other potential health-promoting components. Almost all of the vitamins known to be essential to humans have been detected at some level in milk. Vitamins A, D, E and K are associated with the fat component of milk (Miller *et al.*, 2007). Phosphorus, magnesium, potassium and calcium, in particular, are found at high levels in milk and other dairy foods (Miller *et al.*, 2007).

Table 4 Nutrient composition of Cheddar cheese (Milk SA, 2011)

Per 100 g	Unit		Per 100 g	Unit	
Moisture	g	37. 40			
Energy	kJ	1869. 00			
Energy (Calculated)	kJ	1645. 00			
Protein (N x 6.38)	g	24. 70	**Amino Acids**		
Total Fat	g	32. 30	Total (calculated)	g	25. 10
Carbohydrate (Calculated)	g	1. 28	Arginine	g	0. 86
Lactose	g	0. 23	Serine	g	1. 50
Total Saturated Fat	g	18. 50	Aspartic acid	g	1. 85
4:0	mg	1046. 00	Glutamic acid	g	5. 33
6:0	mg	529. 00	Threonine	g	1. 02
8:0	mg	279. 00	Glycine	g	0. 46
10:0	mg	689. 00	Alanine	g	0. 82
12:0	mg	935. 00	Tyrosine	g	1. 11
14:0	mg	3179. 00	Proline	g	2. 55
16:0	mg	8212. 00	Methionine	g	0. 80
18:0	mg	3585. 00	Valine	g	1. 35
20:0	mg	-	Phenylalanine	g	1. 26
Total Monounsaturated Fat	g	8. 11	Isoleucine	g	1. 01
14:1	mg	268. 00	Leucine	g	2. 21
16:1	mg	424. 00	Histidine	g	0. 77
18:1	mg	7416. 00	Lysine	g	1. 75
Total Polyunsaturated Fat	g	0. 75	Tryptophane	g	0. 29
18:2	mg	619. 00	Cystine	g	0. 11
18:3	mg	131. 00			
Cholesterol	mg	115. 00			
Minerals			**Vitamins**		
Calcium	mg	788. 00	Retinol	µg	344. 00
Iron	mg	0. 78	Beta carotene	µg	85. 00
Magnesium	mg	29. 90	Vitamin B1	mg	0. 04
Phosphorus	mg	532. 00	Vitamin B2	mg	0. 36
Potassium	mg	82. 30	Vitamin B3	mg	0. 08
Sodium	mg	487. 00	Vitamin B6	mg	0. 07
Zinc	mg	3. 78	Folic acid	µg	18. 00
Copper	mg	0. 06	Vitamin B12	µg	0. 83
Chloride	mg	990. 00	Biotin	µg	3. 00
Manganese	µg	74. 40	Vitamin C	mg	trace
Selenium	µg	13. 90	Vitamin D	µg	0. 26
Iodine	µg	39. 00	Vitamin E	µg	1146. 00
Fluorine	µg	34. 90			
Boron	µg	-			
Chromium	µg	11. 80			

8. TRENDS IN THE CHEESE MARKET

A growing awareness of human health and natural products together with conscious spending and convenience are prevailing patterns influencing consumer behaviour within the cheese market.

8.1 Health awareness

Focus on health has intensified as consumers are encouraged to improve their diet, watch their weight and help combat issues of heart disease, obesity and diabetes (Sloan, 2007; Mintel, 2009a; Mintel, 2009b). Cheese has a reputation of a high fat product which often overshadows the nutritional benefits it has to offer. As a result, manufacturers are looking at low and reduced fat options to address the unhealthy status of this category. Consumers, however, are unwilling to compromise on flavour and texture with reduced fat options (Mintel, 2009a; Mintel, 2009b). Euromonitor reports a growing interest in healthier cheese in South Africa, although this is still considered a niche market (Euromonitor, 2008). Sloan (2007) suggests that weight management is the number one health factor affecting food buying behaviour. The trend, referred to as “Doing Without”, proposes that avoidance behaviour is accelerating and products that eliminate or reduce undesirable ingredients such as fat are moving to centre stage. With its high calcium levels, cheese has an intrinsic nutritional value. Closely related to calcium is bone health, a popular functional feature in the dairy sector and important in combating conditions such as osteoporosis (Mintel, 2009b). Children form a small but significant market for cheese, with many products designed for the lunchbox. Sloan (2007) reported that sales of better-for-you kids’ foods / beverages are growing at ten times the rate of mainstream products and more than three times the rate of other kid-driven food categories. Manufacturers are working to reassure parents of the health benefits of cheese by highlighting the high calcium content and reducing additives (Mintel, 2009a).

8.2 Natural products

A growing awareness amongst consumers of the potential dangers of artificial additives and growth hormones has resulted in an increased demand for more natural and less processed dairy products. Whilst this trend has a negative influence on processed cheese, it has benefited the cheese market as a whole, since consumers regard cheese as a natural product (Mintel, 2009a). Organic products have enjoyed a significant level of success in the dairy market. The popularity of organic cheese is driven by concerns of provenance and naturalness. The way in which many of these cheeses are produced reassures consumers of its naturalness and purity (Mintel, 2009a). This in turn helps to counter concerns over health issues such as fat and salt content (Mintel, 2009b). Sloan (2007) suggests that consumers equate organic with nutritional value, freshness, better long-term health and better eating

quality. The author also confirms that nearly two thirds of shoppers who are also parents prefer to buy organic products for their children.

8.3 Consumer spending

Although current economic conditions have resulted in a decline in spending, consumers are still prepared to pay extra for a gourmet or luxury cheese, which is considered a treat. They nevertheless welcome savings on more everyday products (Mintel, 2009a). Supermarkets in particular are responding to a need for savings with a number of value and discount brand cheese products. The recession has boosted the launch of economy cheeses, particularly for everyday use. Consumers are reassessing their purchasing decisions and when purchasing cheese, price/value for money is the most common factor driving choice (Mintel, 2009a; Mintel, 2009b). Premium cheeses have an established place in the market as products to be consumed in their own right. The recession has positively influenced the segment since consumers are now more likely to entertain at home and thus turn to gourmet and indulgent lines to treat themselves and/or their guests. Mature cheeses are used more by those who use cheese for cooking or who eat it after a meal or on special occasions (Mintel, 2009b).

8.4 Convenience

Convenience is a key trend in terms of packaging for the cheese market, helping to reduce wastage and offering an easy to use and on-the-go format for snacking (Mintel, 2009a). Grated cheese has seen a significant increase in usage as it offers convenience, especially for use in cooking (Mintel, 2009b). Sloan (2007) recommends that taking a step out of food preparation is a guaranteed way of increasing sales. Portion size is perhaps the most contemporary form of convenience and the demand for portionable packs and “servings for two” remains unmet (Sloan, 2007). Mintel (2009a) reports that single person households tend to prefer smaller packs as this helps to minimise wastage. Mintel (2009a) confirms that the convenience packaging trend is particularly popular with children who like products such as peelable cheese strings; however, there is a growing interest in these products targeted at adults (Mintel, 2009b). A new late-night eating occasion, light meals for seniors/women, teenage after-school get-togethers and a need to stay satiated until meal time have all made snacks and mini-meals a new and potentially lucrative market.

9 SENSORY ANALYSIS

Sensory analysis is defined as a scientific method used to evoke, measure, analyze and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing (Stone and Sidel, 1993; Lawless and Heymann, 2010). The potential biasing effects of brand identity and other information influencing consumer perception are minimized through the accurate measurement of human responses to foods by sensory evaluation (Lawless and Heymann, 2010).

The various applications of sensory evaluation as noted by Stone and Sidel (1993) include:

- ◊ New product development and/or cost reduction
- ◊ Monitoring competition
- ◊ Product matching
- ◊ Product optimization
- ◊ Process change
- ◊ Cost reduction and/or selection of new source of supply
- ◊ Quality control
- ◊ Quality assurance
- ◊ Determining storage stability
- ◊ Product grading or rating
- ◊ Product sensory specification
- ◊ Raw materials specification
- ◊ Advertising claims
- ◊ Correlation of sensory data with chemical and physical measurements
- ◊ Process/ingredient/analytical and sensory relationships
- ◊ Consumer acceptance and/or consumer preference

9.1 Descriptive sensory analysis

Descriptive sensory analysis (DSA) is a comprehensive, flexible and sophisticated analytical sensory method that provides detailed information on the sensory characteristics of a product (Stone and Sidel, 1993; Murray, Delahunty and Baxter, 2001). The method involves the detection and description of both the qualitative and quantitative aspects of a product by a trained panel (Meilgaard, Civille and Carr, 2007) and may also provide a basis for determining those sensory attributes that are important to consumer acceptance (Stone and Sidel, 1993).

The several different methods of descriptive sensory analysis include the Flavour Profile Method, Texture Profile Method, Quantitative Descriptive Analysis™, the Spectrum Method™,

Free-choice Profiling and generic descriptive analysis. Each reflects various sensory philosophies and approaches and is described by Stone and Sidel (1993); Murray *et al*. (2001), Meilgaard, Civille, and Carr (2007) and Lawless and Heymann (2010). Three aspects, however, form the foundation for any descriptive sensory programme (Murray *et al.,* 2001; Delahunty and Drake, 2004; Lawless and Heymann, 2010). These include selecting a panel, training the panel and quantifying the sensory aspects of a product (Lawless and Heymann, 2010).

9.1.1 Selecting and training judges

Descriptive sensory analysis requires the training of a group of individuals, generally between 6 – 12, to identify and quantify specific sensory attributes or all of the sensory attributes of a food product (Drake, 2007). Murray *et al.,* (2001) suggests that panellists should also have a reasonable level of sensory acuity, although, it is the commitment and motivation of each member that is of utmost importance to the overall success of the sensory project. Piggott and Mowat (1991) identified 22 prospective assessors during the initial training session to evaluate the sensory aspects of maturation of Cheddar cheese. This number decreased, however, to 13 when the selection criteria of availability, interest, motivation and good health was applied. Muir and Hunter (1991/2) drew 24 assessors from a pool of 30 experienced and screened, but untrained members of staff from the Hannah Institute for their panel. To generate a descriptive language for Cheddar cheese, Drake *et al.* (2001), identified 15 members of academia, industry and government for a three day round table discussion. To validate the descriptive language, a final panel of 12 individuals was established (Drake *et al.,* 2001).

The primary goal of training a panel is to produce results that are equivalent to an instrument (Drake, 2007). The training phase begins with the development of a common language which comprehensively and accurately describes the product attributes (Murray *et al.,* 2001). Generally, a consensus or ballot training method is employed by the panel (Lawless and Heymann, 2010) to develop the sensory language (Murray *et al.*, 2001). Alternatively, a sensory language or lexicon with clearly defined terms for each sensory attribute may also be used in the training (Drake, 2007). The final descriptive language, however, should be precisely defined and contain enough terms to include all attributes likely to be encountered (Murray *et al.,* 2001). Hort, Le Grys and Woodman (1997) reduced an initial list of 21 terms describing the perceived textural attributes of Cheddar cheese to seven well defined descriptors.

To further aid training and attribute identification, definition and scale usage, reference standards, either food or chemical, can be provided to the panel (Drake, 2007). These references serve to focus the panel on the general concept of the specified attribute (Drake, 2007). Murray and Delahunty (2000a) determined 21 reference standards (food and chemical)

to characterise the flavour of Cheddar cheese and Drake *et al.* (2001) listed food and chemical reference standards for 28 attributes identified in Cheddar cheese.

The final aspect of training introduces the score sheet to measure the intensity of the specific attribute (Lawless and Heymann, 2010). Generally an unstructured line scale, anchored on either side with "none" to "extreme" or "slight" to "very strong" is applied (Lawless and Heymann, 2010). Piggott and Mowat (1991) implemented a scale where 0 represented "not present" and 5 represented "as much as possible" while measuring the sensory properties of maturing cheese. The authors also issued a questionnaire to the panel to prompt comments from the judges experiencing difficulties with the sensory lexicon. Muir and Hunter (1991/2) applied a 12.5 cm undifferentiated line scale with anchor points at each side to quantify the sensory aspects of maturing cheese.

9.1.2 Determining judge reproducibility

This step in the training determines whether the judges are able to evaluate the samples consistently and reliably, and generally overlaps with the initial training (Lawless and Heymann, 2010). If the judges are not reproducible, further training on the attributes is recommended. Nofima, Norway developed an advanced software programme for analysing panel reliability. This programme is suitable for research-based projects, but also for industry where DSA is conducted (Næs, Brockhoff and Tomic, 2010). Hort *et al.* (1997) examined results from their preliminary training and where judge scores fell consistently more than two standard errors from the mean, the judges were advised to alter their scoring. Ultimately, two judges were removed from the panel as their scoring was inconsistent.

9.1.3 Analysing samples

Lawless and Heymann (2010) recommend that standard sensory practices of sample coding, randomised serving sequence and the used of individualised tasting booths should be employed during the analysis phase of the study. Furthermore, samples should be labelled with 3-digit random numbers and order of presentation randomised (Piggott and Mowat, 1991; Drake *et al.,* 2001). The appropriate experimental design should also be used (Lawless and Heymann, 2010). If the purpose of a study is multivariate analyses, such as discriminant analysis, it is vitally important to use a complete block design, i.e. all panellists must analyse all samples (Næs *et al.*, 2010). Piggott and Mowat (1991) tasted 13 samples of commercial Cheddar cheese and 17 samples of institute cheese in duplicate over ten sessions. Six samples were served per session. Muir and Hunter (1991/2) reported that each of the 12 Cheddar cheeses in their study was evaluated the same number of times, that each judge evaluated each cheese once, that each cheese was evaluated once in each position and finally that each cheese was preceded by every other cheese. Drake *et al.* (2001) judged 24 Cheddar

cheese samples utilising a balanced block design. Two cheeses were tasted per session over a three week period and each session was held at the same time of day.

9.2 Cheddar Cheese and Descriptive Sensory Analysis

Descriptive sensory analysis has been widely applied to document the sensory character of Cheddar cheese (Muir and Hunter, 1991/2; Piggott and Mowat, 1991; Heisserer and Chambers, 1993; Murray and Delahunty, 2000a; and Drake *et al.*, 2001).

Muir and Hunter (1991/2) evaluated the extent and magnitude of order of tasting effects and carry over effects during sensory evaluation using DSA. The authors applied a well-proven vocabulary that was routinely used in their laboratory which included 7 odour, 11 flavour and 5 textural terms. Twenty four assessors rated 12 brands of retail Cheddar cheese ranging in maturity from milk to extra mature. The authors concluded that order of tasting introduces a significant bias to the sensory analysis of Cheddar cheese. Negative attributes such as rancid odour, fruity, rancid, and cowy flavour increase in intensity with order of tasting while those with positive attributes move in the opposite direction.

This sensory vocabulary was applied in further work on Cheddar cheese by Muir and Hunter, (1992); Banks, Hunter and Muir (1994); Muir, Hunter, Banks and Horne (1995); Muir, Banks and Hunter (1996), Muir, Hunter, Banks and Horne (1996) and Muir, Banks and Hunter (1997). Muir and Hunter (1992) in exploring the relationship between perception of maturity and sensory attributes of Cheddar cheese proposed that the perception of maturity could be narrowed down to two attributes, namely, intensity of Cheddar cheese flavour and mouth coating character.

Banks *et al.* (1994) found inconclusive evidence that fat content of cheese was the sole determinant of the differences in the sensory properties of Cheddar cheese ripened over a period of 9 months. Mouth-coating character, a contributor to overall acceptability in full fat cheese (Muir and Hunter, 1992) was associated with fat content and a loose association between salt in moisture content and pasty texture was noted.

Heisserer and Chambers (1993) referenced 30 flavour attributes for natural aged cheese. The attributes were defined and reference standards indicated. The study was conducted on 42 cheeses, of which six were Cheddar cheese of varying maturity. The attributes were described as dairy-like (buttery, cooked milk, dairy-fat, dairy-sour, dairy-sweet), fatty-acid / animal (animalic, butyric, decaying animal, fresh fish, fish oil, goaty, sweaty, waxy), fungal (moldy, mushroom), other aromatics (fermented fruity / winey, fruity, nutty, pineapple, sauerkraut, smokey, soy sauce), mouthfeeling (astringent, biting, pungent, sharp) and fundamental tastes (sweet, sour, salty, bitter). The authors proposed that the objectively determined attributes could be used to describe cheese, instead of subjective judgments based on defects alone.

In identifying the key sensory attributes of hard cheese, Muir *et al.* (1995) suggested that it would be feasible to construct a sensory key for cheese based on selected characteristics. These included flavour (cowy/unclean and creamy), odour (intensity, rancid and creamy) and texture (rubbery, pasty and grainy).

Muir, Banks and Hunter (1996) advised that commercial starter systems could promote substantial differences in the sensory properties of Cheddar cheese and that starter type not only affected ripening rate, but also influenced flavour profile. At the same time, Muir, Hunter, Banks and Horne (1996) profiled the sensory character of commercially produced Cheddar cheese to determine sensory changes over a period of 12 months. The authors concluded that the main changes in sensory character, associated with ripening, were an increase in Cheddar aroma, Cheddar and acid flavour and mouth coating characteristics.

In a study to compare the flavour and texture of Cheddar cheese from farmhouse and factory origin, Muir, Banks and Hunter (1997) confirmed that cheese, produced from unpasteurised milk, had a distinctly different flavour profile to factory made cheese. Of the six unpasteurised samples, five received high ratings for unclean/manorial flavour. In contrast to factory made Cheddar cheese, the farmhouse Cheddar cheese showed wide variations in composition which, in part, were associated with atypical flavour or texture.

In defining Cheddar cheese flavour, Murray and Delahunty (2000a) established food and chemical reference standards to represent 21 flavour concepts of Cheddar cheese. By establishing reference standards to demonstrate flavour concepts, the authors anticipated that a more accurate and precise definition of Cheddar cheese could be achieved. The descriptive language is outlined in Table 8. The vocabulary was further applied in research to establish consumer preference for the sensory and packaging attributes of Cheddar cheese (Murray and Delahunty, 2000b), and consumer preference for Irish farmhouse and factory cheese (Murray and Delahunty, 2000c). Caspia, Coggins, Schilling, Yoon and White (2006) utilised the vocabulary to determine a relationship between descriptive sensory analysis and consumer acceptability of Cheddar cheese.

Drake, *et al.* (2001) identified 17 terms frequently observed in Cheddar cheese and a further ten terms rarely observed in Cheddar cheese. The lexicon is detailed in Table 7. The language was validated in a study published a year later (Drake *et al.,* 2002). The authors concluded that Cheddar cheeses of varying maturity levels have distinctive flavour profiles. Young cheese flavours are characterised by cooked / milky, whey, diacetyl and milk fat flavours. As the cheese ages, however, sulphur, brothy, nutty, fruity and catty flavours develop (Drake *et al.*, 2001; *Drake et al.*, 2002).

Further research based on this Cheddar cheese language includes Suriyaphan *et al.* (2001), Avsar, Daragul-Yuceer, Drake, Singh, Yoon and Cadwallader (2004), Singh *et al.* (2005) Cadwallader *et al.* (2006), Carunchia Whetstine, Drake, Broadbent and McMahon (2006a)

Carunchia Whetstine, Drake, Nelson, and Barbano (2006b) and Carunchia Whetstine, Luck, Drake, Foegeding, Gerard, and Barbano (2007).

Suriyaphan *et al.* (2001) reported that in British farmhouse Cheddar cheese, the "cowy-barny" note was produced by *p*-Cresol, whereas the intense "soil-like" note was due to 2-isopropyl-3-methoxypyrazine. At a lower odour intensity, 2-isobutyl-3-methoxypyrazine contributed to a "bell pepper-like" note. The Strecker aldehydes, 2/3-methyl butanal and 2-methyl propanal, derived from valine, leucine and isoleucine (Singh *et al.,* 2003) were determined by Avsar *et al.* (2004) to have played a central role in the nutty flavour of Cheddar cheese. Singh *et al.* (2005) characterised the sensory aspects of a bitter peptide from β-casein by incorporating descriptive sensory analysis to confirm that the threshold levels were based on bitter taste detection and not some other stimuli provided by the purified peptide. Compounds responsible for the beefy/broth-like aroma note commonly found in aged Cheddar cheese were identified by Cadwallader *et al.* (2006) as methional, furaneol and 2-methyl-3-furanthiol (MFT). The authors further suggested that the origins of these compounds could be explained by the catabolic activity of the starter bacteria and/or Maillard reaction. Carunchia Whetstine *et al.* (2006a) demonstrated the advantages of linking descriptive sensory analysis, flavour chemistry and starter culture biochemistry to determine whether the addition of a culture adjunct could promote nutty flavour development in Cheddar cheese. From a sensory perspective, Carunchia Whetstine *et al.* (2006b) confirmed that compounds responsible for milk fat/lactone and cooked/milky flavour as well as the basic tastes were retained in the aqueous phase of the cheese. The authors reported that when fat was removed from aged full-fat Cheddar cheese, most of the flavour and flavour compounds remained in the cheese.

Texture plays an important role in consumer perception of cheese quality and acceptability (Jack, Piggott and Paterson, 1984; McEwan, Moore and Colwill, 1989). Textural attributes furthermore function as key parameters of determining cheese variety (Lawrence, Creamer and Gilles, 1987). O'Callaghan and Guinee (2004) defined cheese texture as a composite sensory attribute resulting from a combination of physical properties that are perceived by the senses of touch (including kinaesthesis and mouth-feel), sight and hearing, but not by the senses of smell and taste.

Cheese texture ripening is mediated by residual coagulant, indigenous milk enzymes, starter bacteria and their enzymes, nonstarter lactic acid bacteria and their enzymes, secondary microorganisms and their enzymes and in some cases exogenous enzymes (Fox *et al.*, 2000). Lawrence *et al.* (1987) proposed two distinct phases in texture development that take place during ripening. During the first phase, which occurs in the first 7 – 14 days after manufacture, the rubbery texture of the young cheese curd is rapidly converted into a smoother and more homogenous product. A weakening of the para-casein network of the curd results in this softening (O'Mahony, Sheehan, Delahunty and McSweeney, 2006). The second phase sees a

more gradual change in texture as the α_{s1}-casein and other caseins are broken down in a time scale measured in months rather than days. The second phase occurs for the duration of ripening and involves more gradual changes in texture due to change in pH and continued proteolysis (Lawrence *et al.*, 1987; O'Mahony *et al.*, 2006).

From a sensory perspective, however, Hort and Le Grys (2001) proposed three distinct stages in the ripening of Cheddar cheese. The initial stage covers the period up to 18 weeks. During this time, a considerable reduction in springiness, an increase in crumbliness and a decrease in stress at fracture is to be expected. The second stage, up to week 34, reflects little change in the textural attributes of the cheese, but variation in the rheological properties. The final stage of maturation indicates a further decrease in springiness and an increase in crumbliness and creaminess.

The texture of Cheddar cheese is primarily determined by its pH and intact casein ratio to moisture. A relatively low moisture cheese, such as Cheddar, becomes increasingly harder with age and more resistant to slight deformation. As proteolysis continues, less water is available for the hydration of the protein matrix, which results in a less easily deformable and harder cheese (Lawrence *et al.*, 1987). Textural differences in Cheddar cheese are generally attributed to diversity in composition (Piggott and Mowat, 1991; Muir and Hunter, 1992; Muir *et al.,* 1997) and it is accepted that cheese texture changes during aging (Banks *et al.,* 1994, Muir *et al.,* 1996; Hort and LeGrys, 2001; Guinee and Fox, 2004).

Initial terms used to characterise Cheddar cheese texture were published by Piggott and Mowat during 1991. These terms are listed as dry, hard/soft to firm, coarse, creamy, moist, smooth, sticky, grainy, crumbly, rubbery, chewy, pasty, mouth-coating. Unfortunately no descriptors were outlined and neither was a scale.

Muir and Hunter (1991/2) listed five attributes – firmness, crumbly, pasty, grainy and mouth-coating to identify the carry-over effect and order of tasting effects during sensory evaluation of Cheddar cheese. Further research by Muir and Hunter (1991/2); Muir and Hunter (1992); Banks *et al.* (1994), Muir *et al.* (1996), Muir *et al. (*1997) and Shakeel-Ur-Rehman (2000) also incorporated these textural terms.

It was only towards the end of the decade that descriptors and intensities were included as part of a texture language. Hort, Le Grys and Woodman (1997) identified seven terms that were well defined and could be quantified on line scales with anchors at each end of the scale. This texicon was employed in further research by Hort and Le Grys (2000) to identify the perceived textural characteristics and measure the rheological properties of Cheddar cheese and in 2001 to assess the textural and rheological changes that occurred in an English Cheddar as it matured (Hort and Le Grys, 2001).

Table 5 outlines noteworthy sensory and consumer studies of Cheddar cheese. Table 6 is a compilation of the lexicons employed to characterise the sensory aspects of Cheddar cheese. Table 9 lists the terms used to describe the texture of Cheddar cheese.

Table 5 Summary of the most important sensory and consumer preference studies on Cheddar cheese.

Authors	Title	Objective	Methodology	Main Output
Descriptive sensory studies of Cheddar cheese				
Piggott and Mowat, 1991	Sensory aspects of maturation of Cheddar cheese by descriptive analysis.	To develop a descriptive sensory analysis procedure that could be used to follow the sensory changes during the early stages of Cheddar cheese maturation.	The authors refer to the procedure as quantitative descriptive analysis, however, not in the true form of QDA. Generic descriptive analysis, with consensus training and questionnaire, to determine assessor difficulties regarding scoring.	Developed a descriptive sensory analysis procedure to follow the flavour and texture changes in maturing Cheddar cheese. The sensory language consisted of one colour, two aroma, eight flavour and nine texture terms. A scale was also designed to measure attribute intensity, where 0 represented "not present" and 5 represented "as much as possible".
Muir and Hunter, 1991/2	Sensory evaluation of Cheddar cheese – Order of tasting and carryover effects.	To evaluate the extent and magnitude of order of tasting effects and carryover effects during sensory evaluation of a wide range of commercially available Cheddar cheese.	Quantitative descriptive analysis (QDA).	Confirmed seven odour, 11 flavour and five texture terms to characterise Cheddar cheese. Furthermore, recommendations were made regarding tasting cheese in specifically designed, order rather than in a systematic or random fashion.
Hort, Le Grys and Woodman, 1997	Changes in the textural properties of Cheddar cheese during maturation.	To investigate the changes in textural properties that occur in one particular variety of Cheddar cheese during ripening.	Generic Descriptive Sensory Analysis based on consensus training.	Established seven terms and well defined descriptors for Cheddar cheese texture. The study also revealed a strong relationship between age and the textural attributes of Cheddar cheese when restricted to one particular variety.

Murray and Delahunty, 2000a	Selection of standards to reference terms in a Cheddar-type cheese flavour language.	To determine reference standards for 21 flavour terms representing assessor concepts of Cheddar cheese flavour.	Generic Descriptive Sensory Analysis incorporating Free Choice Profiling (FCP) for term generation, focus group techniques and consensus training for language development and concept formation.	Established food and chemical reference standards for 21 Cheddar cheese flavour concepts with the hope of achieving a more accurate and precise definition of Cheddar cheese flavour.
Drake *et al.*, 2001	Development of a descriptive language for Cheddar cheese.	To develop a standardised language for Cheddar cheese.	Terms developed over three days of discussion by 15 cheese experts from academia, industry and government. Fine tuning and identification of references during 75 hours training with the Spectrum™ method.	Developed a standardised descriptive language for Cheddar cheese, comprising 17 commonly identified terms. Descriptors and reference standards were developed and validated which facilitated training of sensory panels at different sites and enhanced communication of cheese flavour research results.
Preference Mapping Studies of Cheddar cheese				
Roberts and Vickers, 1994	Cheddar cheese aging: Changes in sensory attributes and consumer acceptance.	1. To investigate changes in intensity of a comprehensive set of sensory attributes in Cheddar cheese during 9 months of ripening. 2. To study the relationship between sensory attributes and consumer liking for Cheddar cheese. 3. Develop a mathematical model	Generic descriptive sensory analysis with consensus training to develop 54 defined attributes with corresponding rating scales. 120 consumers rated their liking for cheeses aged to three, six and 9 months.	54 attributes identified and defined to characterise Cheddar cheese. One of the earliest papers to investigate sensory attributes and consumer liking. As the cheeses aged, strong flavours, off flavours and young flavours increased in intensity. Off flavours correlated negatively with liking and young flavours correlated positively with

		which would predict consumer liking for aged Cheddar cheese, based on sensory characteristics at a young age.		liking, regardless of the age of the cheese. The presence of off flavours increased the probability of the cheese being disliked.
Murray and Delahunty, 2000b	Mapping consumer preference for the sensory and packaging attributes of Cheddar cheese.	To provide a methodology which allows for a broader assessment of product acceptability as it integrates consumer preferences from sensory and packaging perspectives.	Terms and reference standards based on Murray and Delahunty, 2000. Texture and appearance terms and descriptors followed a similar methodology in development. 207 consumers tasted eight cheese samples and rated their preference on a nine-point hedonic scale.	Preference mapping and Hierarchical Cluster Analysis provided visual material to compare the preference of each consumer and identified four clusters of consumers who were homogenous in their preference of Cheddar cheese.
Young *et al.*, 2004	Preference mapping of Cheddar cheese with varying maturity levels.	To evaluate the flavour profile and consumer acceptability of seven Cheddar cheese with varying maturity levels using descriptive analysis and consumer acceptance tests.	Descriptive analysis based on the cheese flavour sensory language developed by Drake *et al.*, 2001. 100 consumers each at two locations tasted seven cheeses and rated their preference on a nine-point hedonic scale. Demographic information and consumer evaluation of the cheese was also collected.	Six distinct consumer segments were identified. The concept of Cheddar cheese flavour varied widely among consumers; however, consumers distinguished aged cheeses from young cheeses. Cheddar cheese acceptance related to maturity level and flavour characteristics. Acceptance furthermore varies widely among consumers with specific segments preferring specific Cheddar flavour profiles.
Caspia *et al.*, 2006	The relationship between	To determine how descriptive	Generic descriptive sensory	Six clusters of consumers with

	consumer acceptability and descriptive sensory attributes in Cheddar cheese.	attributes, including taste, aroma and textural attributes in commonly consumed Cheddar cheeses, related to consumer acceptability, using preference mapping and logistic regression.	analysis, incorporating previously identified languages for sensory analysis of Cheddar cheese by Murray and Delahunty, 2000a and Drake *et al.,* 2001. Food and chemical references, and a 15-point intensity line scale were employed.140 consumers ranked the three cheeses in order of preferences and then evaluated using a 9-point hedonic scale. Each consumer evaluated for overall acceptability, overall flavour, aroma, texture and appearance.	difference cheese preferences were obtained, confirming the differences in preferences of cheese taste among the different consumer segments. Furthermore, neither texture nor aroma could be used to relate descriptive sensory analysis to consumer preference. Flavour, however, related well to consumer preference of Cheddar cheese.

Table 6 Sensory languages used to profile Cheddar cheese.

References	Lexicons	
Piggott and Mowat, 1991	Appearance	White to orange
	Flavour	Milky, buttery, cheesy, mouldy, rancid, pungent, processed, strength, maturity, aftertaste
		Salty, sour, bitter
	Taste	Sour, sweet
	Texture	Dry, hard/soft to firm, coarse, creamy, moist, smooth, sticky, grainy, crumbly, rubbery, chewy, pasty, mouth-coating
Drake *et al.,* 2001, 2002, 2005 Young *et al*., 2004 Carunchia Whetstine *et al.,* 2006a Carunchia Whetstine *et al.,* 2006b		Cooked, whey, diacetyl, milkfat/lactone, fruity, sulphur, free fatty acid, brothy, nutty, catty, cowy/phenolic, age, yeasty, mouldy/musty, methyl ketone/blue, oxidized, waxy/crayon, faecal, bell pepper, rosy/floral, scorched, nutty, bitter, salty, sweet, sour, umami, prickle/bite.
Heisserer and Chambers, 1993		Buttery, cooked milk, dairy fat, dairy sour, dairy sweet, animalic, butyric acid, decaying animal, fresh fish, fish oil, goaty, sweaty, waxy, fermented/fruity/winey, nutty, pineapple, sauerkraut, smokey, soy sauce, mouldy, mushroom, astringent, biting, pungent, sharp, bitter, salty, sour, sweet.
Hort, Le Grys and Woodman,1997 Hort and Le Grys 2000, 2001	Texture	Creaminess, crumbliness, firmness, hardness, springiness, graininess, chewiness

Muir and Hunter, 1991/2 Muir *et al.,* 1995 Muir *et al.*, 1996 Muir *et al.* 1997	Odour	Intensity, creamy, sulphur, fruity, nutty, rancid, other
	Flavour	Cheddar intensity/overall intensity, creamy/milky, sour/acid, sulphur/eggy, fruity/sweet, nutty, rancid, bitter, cowy, unclean/manorial, salty, other
	Texture	Firmness, rubbery, crumbly, pasty, grainy, mouth-coating
Murray and Delahunty, 2000 a, b, c Bogue, Delahunty, Henry and Murray, 1999	Aroma	Pungent, caramel, sweaty/sour, sweet, creamy, fruity
	Flavour	Pungent, caramel, sweaty, creamy, fruity, buttery, rancid, Cheddary, mushroom, mouldy, nutty, smoky, soapy, processed, sweet, salty, acidic, bitter, astringent, strength, balanced
	Appearance	Colour intensity, mottled, uniformity, open, shiny
	Texture	Firm, rubbery, crumbly, smooth, moist, grainy, mouth-coating

Table 7 Cheddar Cheese lexicon developed by Drake *et al.* (2001).

Term	Definition	Reference
Cooked	Aromatics associated with cooked milk	Skim milk heated to 85°C for 30 minutes
Whey	Aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Diacetyl	Aromatics associated with diacetyl	Diacetyl, 20 ppm
Milkfat / Lactone	Aromatics associated with milkfat	Fresh coconut meat, heavy cream, δ dodecalactone, 40 ppm
Fruity	Aromatics associated with different fruits	Fresh pineapple, ethyl hexanoate, 20 ppm
Sulphur	Aromatics associated with sulphurous compounds	Boiled mashed egg, H_2S bubbled through waterstruck match
Free fatty acid	Aromatics associated with short chain fatty acids	Butyric acid, 20 ppm
Brothy	Aromatics associated with boiled meat or vegetable soup stock	Canned potatoes, Wylers low sodium beef broth cubes, methional, 20 ppm
Nutty	The nut-like aromatic associated with different nuts	Lightly toasted unsalted nuts, wheat germ, unsalted wheat thins, roasted peanut oil extract
Catty	Aroma associated with tom-cat urine	2 mercapto-2 methyl-pentan-4-one, 20 ppm
Cowy / phenolic	Aromas associate with barns and stock trailers, indicative of animal sweat and waste	p-cresol, 160 ppm, band aids
Age**	Flavours indicating age in Cheddar cheese	Aged Cheddar cheese (1 y or longer)
Yeasty*	Aromatics associated with fermenting yeast	Raw yeast dough, yeast in 3% warm sucrose water
Mouldy / Musty*	Aromas associated with moulds and / or freshly turned soil	2-ethyl-1-hexanol, potting soil
Methyl Ketone / bleu*	Aroma associated with blue-veined cheese	2-octanone, 40 ppm
Oxidized*	Aroma associated with oxidized fat	2,4 decadienal, 20 ppm
Waxy / Crayon*	Aromatics associated with medium chain fatty acids	Capric acid, lauric acid or decanoic acid, 100 mg / ml
Fecal*	Aroma associated with complex protein decomposition	Indole, skatole, 20 ppm
Bell Pepper*	Aroma associated with freshly cut green vegetables	Methoxy pyrazines, 5 ppb, freshly cut bell pepper
Rosy / Floral*	Aroma associated with flowers	2-phenethylamine, 20 ppm
Scorched*	Aroma associated with extreme heat treatment of milk proteins	Milk heated to 121 °C for 25 min
Bitter	Fundamental taste sensation elicited by caffeine, quinine	Caffeine (0.08% in water)
Salty	Fundamental taste sensation elicited by salts	Sodium chloride (0.5% in water)

Sweet	Fundamental taste sensation elicited by sugars	Sucrose (5% in water)
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08% in water)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	MSG (1% in water)
Prickle / bite*	Chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water

* Indicates term was not frequently encountered in Cheddar cheese.

** Data analysis indicated term is redundant and is a combination of several terms.

Chemical references prepared in 95% ethanol.

Table 8 Descriptive Language used to characterise Cheddar-type cheese flavour (Murray and Delahunty, 2000a).

Flavour Term	Definition	Food Reference Standard	Chemical Reference Standard
Pungent	A physically penetrating sensation in the nasal cavity. Sharp smelling or tasting.	Rosenberg Danish blue cheese	Ammonia – 1% in PG[1]
Caramel	The taste and aromatics associated with burnt sugar or syrup; toffee made with sugar that has been further melted.	Nestle condensed milk	3-hyroxy-2-methyl-4-pyrone 2% in PG
Sweaty	The taste and aromatics reminiscent of perspiration generated food odour which are sour, stale and slightly cheesy.	Processed cheese (30°C for 3 hours)	Isovaleric acid 0.1% in PG
Creamy	Fatty, creamy tasting, of the nature of, or containing cream.	Italian Mascarpone cheese	Y-Decanolactone 0.1% in PG
Fruity	The taste and aromatic blend of different fruit identities.	Sno fruit of the forest yoghurt	Ethyl-butyrate 0.1% in PG
Buttery	Fatty, buttery tasting, of the nature of, or containing butter.	Kerrygold unsalted butter	Diacetyl 1% in PG
Rancid	The taste and aroma associated with sour milk and oxidized fats. Having the rank unpleasant aroma of taste characteristic of oils and fats when no longer fresh.	Processed cheese (21°C for 4 days)	Butyric acid 0.1% in PG
Cheddary	The taste and aromatics associated with typical Cheddar.	Galtee processed cheese	No chemical tested
Mushroom	The taste and aromatics associated with raw mushrooms.	Brown mushrooms chopped	1-octene-3-ol 0.5% in PG
Moldy	The taste and aromatics associated with moulds. They are usually earthy, dirty, stale, musty and slightly sour.	English Stilton cheese	2,4,6 trichloroanisole 1% in PG
Nutty	The non-specific nut like taste and aromatics characteristic of several different nuts e.g. peanuts, hazelnuts and pecans.	Shamrock mixed crushed nuts	2-acetyl-pyridine 0.01% in PG
Smoky	The penetrating smoky taste and aromatics, similar to charred wood. Tainted by exposure to smoke.	English Applewood cheese	Guaiacol 0.5% in PG

Soapy	A detergent like taste and smell. Similar to when a food is tainted with a cleansing agent.	Goldenvale mellow processed Cheddar	1-octanol 1% in distilled H_2O
Processed	A bland, shallow and artificial taste. Made by melting, blending and frequently emulsifying other cheeses.	Goldenvale cheese strings	No chemical tested
Sweet	The fundamental taste sensation of which sucrose is typical.	Nestle condensed milk	Sucrose 1% in distilled H_2O
Salty	The fundamental taste sensation of which sodium chloride is typical.	Pecorino Romano sheep's cheese	Sodium chloride 1% in distilled H_2O
Acidic	A sour, tangy, sharp, citrus-like taste. The fundamental taste sensations of which lactic and citric acids are typical.	Bio-Danone natural yoghurt	Citric acid 0.2% in distilled H_2O
Bitter	A chemical-like taste. The fundamental taste sensations of which caffeine and quinine are typical.	Schweppes tonic water	Quinine 0.01% in distilled H_2O
Astringent	A mouth-drying and harsh sensation. The complex of drying, puckering and shrinking sensations in the lower cavity causing contraction of the body tissues.	Lyons tea – 6 bags/distilled H_2O for 3 hours	Tannic acid 0.05% in distilled H_2O
Strength	The overall intensity of aroma and flavour, the degree of mildness and maturity.	English blue Stilton cheese	No chemical tested
Balanced	Mellow, smooth, clean. In equilibrium, well arranged or disposed, with no constituent lacking or in excess.	KVI Cheddar	No chemical tested

[1] PG = Propylene Glycol

Table 9 Terms used to describe the texture of Cheddar cheese.

Author	Terms
Piggott and Mowat, 1991	Dry, hard / soft, coarse, creamy, moist, smooth, sticky, grainy, crumbly, rubbery, chewy, pasty, mouth-coating.
Muir and Hunter, 1991/2	Firmness, rubbery, crumbly, pasty, grainy, mouth-coating.
Hort *et al.,* 1997	Creaminess: The extent to which the cheese has a velvety mouthfeel *Not very creamy to very creamy* Crumbliness: The extent to which the sample breaks when chewed or compressed Fingers *Not crumbly to very crumbly* Chewing *Not crumbly to very crumbly* Firmness: The force required to compress the cheese with the fingers *Soft to firm* Hardness: The force required to penetrate the cheese with a knife or the teeth Cutting *Not very hard to very hard* First Bite *Not very hard to very hard* Springiness: The extent to which the cheese springs back when compressed *Not springy to very springy*
Bogue *et al.,* 1999 Murray and Delahunty, 2000a	Firm, rubbery, crumbly, smooth, moist, grainy, mouth-coating.

10 STATISTICAL RESEARCH METHODOLOGIES

10.1 Preference mapping

Preference mapping is a multivariate statistical technique used to identify the underlying dimensions believed to drive consumer preference and choices (Moskowits, Beckley and Resurreccion, 2006; Van Kleef, Van Trijp, and Lunign, 2006). Two sets of data are required for this technique to be successful, namely that collected from consumer acceptance testing and data collected from the sensory and / or instrumental analysis of the product under review (Lawless and Heymann, 2010). The procedure has been applied extensively to provide a visual representation of the association between product, its sensory attributes and consumer preferences (Murray and Delahunty, 2000a; Murray and Delahunty, 2000b; Young *et al.*, 2004; Caspia *et al.,* 2006 and Drake *et al.*, 2008). The method requires an objective characterisation of a products sensory attributes, achieved by descriptive analysis, which is then related to preference ratings for the product obtained from a representative sample of consumers (Murray and Delahunty, 2000a).

Internal preference mapping identifies patterns of preference (Schlich, 1995) and uses consumer acceptance ratings to locate the products on the maps (Meilgaard, Civille, and Carr, 2007). Internal preference mapping entails the principal component analysis (PCA) of the matrix of consumer hedonic scores across the products (the observations) and the consumers (the variables). The result of internal preference mapping is a sample map based on the product acceptability information provided by each consumer. A segmentation analysis of consumers is then possible by visually examining the plot of consumer preference directions, or by using a classification algorithm, using the PCA parameters (McEwan, 1996).

External preference mapping uses sensory descriptive attribute ratings to locate the products on the maps (Meilgaard *et al.*, 2007). A sensory explanation of these patterns of consumer preference is then proposed. Individual consumer preferences are regressed onto the first two principal components of the covariance matrix to descriptive or other analytical ratings across products. The aim here is to either improve current products or to develop successful new products (Schlich, 1995).

10.2 Cheddar cheese and preference mapping

Several international studies have been published combining preference mapping techniques and Cheddar cheese (Murray and Delahunty, 2000a; Murray and Delahunty, 2000b; Young *et al.,* 2004, Caspia *et al.*, 2006; Drake *et al.*, 2008). Murray and Delahunty (2000a) assessed the consumer preference for the intrinsic sensory and the extrinsic packaging attributes of Cheddar cheese using preference mapping. Eight cheeses were characterised by 15 assessors, using 32 sensory attributes of aroma, flavour, texture and appearance. Two hundred and seven

Cheddar cheese consumers were asked to provide preference ratings for the sensory characteristics of the cheese samples on a nine point hedonic scale. An internal preference map illustrated the direction and intensity of individual consumer preferences for the sensory attributes and allowed preference for each cheese to be compared. Hierarchical cluster analysis of the data identified four clusters of consumers who were homogenous in their preferences. The authors were further able to identify the relationship between purchase habits and preference for cheese, and identified that older consumers rated mature cheese highly, middle aged consumers preferred mature cheese with strong flavours and younger consumers liked mild flavoured cheese.

Murray and Delahunty (2000b) published further work on consumer preference for Irish farmhouse and factory cheeses. Six farmhouse and two factory-produced Cheddar cheeses were assessed by a trained panel, using descriptive sensory analysis. Approximately 200 consumers were asked to express their preference for the cheeses on a nine point hedonic scale. The data was subjected to PCA and hierarchical cluster analysis. Four clusters of consumer were identified. The authors confirmed that this model could be used to identify how cheeses could be changed slightly to improve their appeal to consumers.

In evaluating the sensory profile and acceptability of seven Cheddar cheeses of varying maturity levels, Young *et al.* (2004) identified six clusters of consumers through the application of preference mapping. The authors confirmed that consumers were able to distinguish between aged and young flavours, and suggested that Cheddar cheeses with specific flavour profiles could be marketed to specific target market segments (Young *et al.,* 2004).

Caspia *et al.* (2006) used preference mapping to determine the relationship between the sensory attributes of Cheddar cheese, as well as consumer acceptance of the samples. A trained panel of nine evaluated seven, nine and 12 month old cheeses. The senven and nine month old cheeses were characterised by cooked, creamy and buttery flavours whereas the 12 month old cheese was described as having fruity aromas, sulphur, earthy and free fatty acid flavours. One hundred and forty consumers were asked to rank the cheeses in order of preference for overall acceptability, flavour, aroma, texture and appearance. Results indicated that the nine month old cheese was the most preferred, followed by the seven and 12 month old cheese. External preference mapping was applied to the data and six clusters of consumers with varying Cheddar cheese preferences were identified. Interestingly, consumers in three of the clusters preferred the young flavours of cooked, buttery and creamy identified in the seven and nine month old cheese. Only one cluster of 13 people preferred the flavours characterising the 12 month old cheese.

Drake *et al.* (2008) combined the preference data of 215 consumers with that of the sensory profiles of nine commercially labelled mild Cheddar cheeses. Their aim was to determine whether distinct flavour profiles existed for mild Cheddar cheese as well as the influence these

flavour profiles had on consumer preferences. Four distinct clusters of consumer were identified and the authors confirmed that colour, cooked/milky, whey and brothy flavours, together with sour taste, were key drivers of acceptability for mild Cheddar cheese. It is interesting to note that although flavour and colour influenced consumer preference, texture did not appear to influence overall liking of the cheese.

Traditional market research and sensory test methods that rely on averaged preference data may not optimise preference for the majority of consumers. Since preference mapping has the ability to define the most favourable or "optimal" product for consumer segments, it provides an advantage to researchers aiming to better understand consumer acceptance (Murray and Delahunty, 2000a).

11 CONCLUSIONS

Cheddar cheese flavour is a crucial component of consumer acceptability (Dacremont and Vickers, 1994). However, Cheddar cheese flavour *per se* is complex, difficult to conceptualise and often a challenge to define in terms of sensory quality (Delahunty and Drake, 2004). By its very nature, cheese is a physically, biochemically and biologically dynamic product. No two batches are ever expected to be identical (Fox and McSweeney, 2004). Add to this manufacturing variables and maturation environments and a potentially astonishing matrix of flavour development is possible. Flavour profiles, nevertheless, are evident as Cheddar cheese matures. Young Cheddar cheese is often described by creamy and buttery attributes while sulphur, nutty, brothy, fruity, umami and rancid flavours tend to characterise aged Cheddar cheese (Drake *et al.*, 2001; Drake *et al.,* 2002). Moreover, textural changes also occur during aging and are mainly attributed to diversity in composition (Lawrence *et al.,* 1987).

Descriptive sensory analysis is one of the most sophisticated and comprehensive methods to detail the sensory characteristics of Cheddar cheese (Murray *et al.*, 2001; Drake, 2007). Two papers in particular have driven research into the sensory profiling of Cheddar cheese. Murray and Delahunty (2000a) published reference standards to demonstrate flavour concepts for Cheddar cheese in the hope of establishing a more accurate and precise definition of Cheddar cheese flavour. A year later, Drake *et al.* (2001) confirmed a descriptive sensory language for Cheddar cheese, which contained attributes, descriptors and reference standards for seventeen terms commonly identified in Cheddar cheese. Both lexicons are recognised for their significant contribution to defining and understanding the sensory nature and quality of Cheddar cheese flavour. A distinct advantage of descriptive sensory analysis is the data that can be used in conjunction with that drawn from consumer analysis. The two sets of data are combined in a statistical technique called preference mapping. As a result, a visual map of the factors believed to drive consumer preference and choices is generated (Van Kleef *et al.,*

2006) demonstrating the relationship between a product, its sensory attributes and consumer liking is created (Murray and Delahunty, 2000a).

Cheese is a nutritious and wholesome dairy product that supplies high quality protein, vitamins and minerals to the human diet (O'Brian and O'Connor, 2004). Consumer attitudes vary towards cheese (Young *et al.*, 2004). Demographics (Drake *et al.,* 2005), prior experience with cheese, the type of cheese consumed and the variety tasted (Dacremont and Vickers, 1994) influence consumer acceptance and repeat purchase. Worldwide trends however, indicate a growing awareness of healthy eating and natural products together with a need for greater product convenience (Euromonitor, 2008; Mintel, 2009a; Mintel, 2009b). Cheese falls well within these boundaries and satisfies the requirements of each trend as a natural and healthy food that is easy and convenient to consume.

To further capitalise on these trends, producers and marketers of Cheddar cheese require a better understanding of the flavours that drive Cheddar cheese consumption, as well as a greater appreciation of the needs, attitudes and perceptions of this segment of consumers. Following enquiries, it was concluded that no specific data exist detailing sensory profiling and consumer acceptance of Cheddar cheese in South Africa.

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CHAPTER 3

THE SENSORY CHARACTERISATION OF SIX CHEESE SAMPLES BY A TRAINED PANEL

1. INTRODUCTION

Cheddar cheese is a biochemically dynamic product (Fox and McSweeney, 2004) which is considered marketable at any time, between two and twelve months of ripening (Green and Manning, 1982). Consequently, the wide range of acceptable flavour and texture characteristics within the category make it difficult to provide one definition for Cheddar cheese flavour (Fox, Guinee, Cogan and McSweeney, 2000). Cheddar cheese characteristically develops from mild flavours of creamy, buttery and cooked milk to the more complex aged flavours of fruity, brothy, nutty and catty (tom cat urine) as it matures (Piggott and Mowat, 1991; Drake, McIngvale, Gerard, Cadwallader and Civille, 2001). The targeted flavour profile, however, is defined by consumers and influenced by their expectations, culture, ethnicity and end application (Lawrence, Gilles, Creamer, Crow, Heap, Honoré, Johnston, and Samal, 2004; Drake, Yates, Gerard, Delahunty, Sheehan, Turnbull, and Dodds, 2005).

Judging and grading are used extensively in the dairy industry to evaluate the sensory properties of all dairy products (Drake *et al.,* 2005; Muir, 2010). Most grading systems involve a single overall value judgment of quality that is arrived at by the addition of separate values for flavour/body/texture/colour and appearance (Muir, 2010). It is a defect-based judgment centred on the presence or absence of specific defects (Drake *et al.,* 2005). Although important for quality control, the technique has its drawbacks. As the score is based on the opinion of one individual, it is subjective rather than specifically defined (Drake *et al.,* 2005). Neither does the method allow for the effects of order of tasting or carry-over, which may lead to biased decisions (Muir and Hunter, 1991/2). Furthermore, due to non-linearity, the scores are not suitable for statistical analysis and thus have limited application in research (Drake *et al.,* 2005). Muir (2010) reports that although grading schemes have developed to measure the reliability and reproducibility of the cheese factory and its processes, an increasing need has arisen for a more informative system, one that is based on positive as well as negative attributes. Since the current grading and judging of Cheddar cheese is unable to meet these requirements, Muir (2010) further proposes that a revised sensory assessment has to be found to satisfy consumer demands.

As a technique to characterise and profile consumer products, DSA is a powerful sensory test available to cheese makers, factories and technologists (Lawless and Heymann, 2010). This scientific method can detect and describe both the qualitative and quantitative aspects of a food product (Meilgaard, Civille, and Carr, 2007). It is a panel of extensively trained judges that perceive and measure aspects of aroma, taste, flavour, texture, aftertaste and sound properties of the product (Murray, Delahunty, and Baxter, 2001). The implementation of a descriptive sensory programme includes the selection of a panel of judges, descriptive attribute generation, training of the judges, determining judge reproducibility and finally analysing the samples (Murray *et al.,* 2001; Lawless and Heymann, 2010).

From a dairy and specifically a cheese perspective, descriptive sensory analysis has been successfully applied to develop a lexicon for Cheddar cheese (Drake *et al.,* 2001) and reference standards to define Cheddar cheese flavour (Murray and Delahunty, 2000a), thus enhancing communication between research groups (Drake, Gerard, Wright, Cadwallader and Civille, 2002; Drake *et al.,* 2005). The method has also been utilised to compare flavour attributes with instrumental analysis of Cheddar cheese (Cadwallader, Drake, Carunchia-Whetstine, and Singh, 2006), to understand the influence of processing on flavour development in Cheddar cheese (Carunchia-Whetstine, Drake, Nelson and Barbano, 2006), the influence of maturation on flavour development (Piggott and Mowat, 1991; Muir, Hunter, Banks and Horne, 1996) and identification of niche marketing opportunities and end-product optimisation (Murray and Delahunty, 2000b; Young, Drake, Lopetcharat and McDaniel, 2004*)*. Furthermore, DSA has been used to evaluate changes in flavour due to ingredient modifications (Kim, Drake, and Drake, 2011) and may also be used for quality control, benchmarking and understanding consumer responses in relation to a products' sensory attributes (Murray *et al.,* 2001). Its greatest strength, however, lies in its ability to allow relationships between descriptive sensory and instrumental or consumer preference data (Murray *et al.,* 2001).

The primary objective of this study was to characterise the appearance, aroma, flavour and texture profile of six cheese samples by means of DSA. A secondary objective was to determine whether the sensory attributes distinguished the cheese samples by age and finally, to establish whether attribute intensities differed as the cheese samples matured.

2. MATERIALS AND METHODS

2.1 Cheese samples

Six commercial cheeses, manufactured in the Western Cape, South Africa were supplied for DSA. Cheeses were selected according to age and encompassed a broad range of maturity levels, varying from 1 and 2 months for the Gouda and Edam cheeses to 4, 8, 15 and 32 months, respectively, for the Cheddar cheeses. Cheeses were produced with pasteurised milk and all, except for the Edam cheese were coloured. The Gouda and Edam were manufactured to include a curd-washing step and both cheeses were salt brined. The Edam was produced with a reduced fat content. The four Cheddar cheeses were manufactured according to a standard Cheddar cheese recipe. Nine kilograms of each cheese was delivered to Stellenbosch University, Department of Food Science on 25th March 2010, where they were stored in the dark at 6°C, until sensory analyses were conducted. Compositional data, listed in Table 1, for moisture, fat and salt content, as well as final pH, was supplied by the manufacturer.

Table 1 Compositional data supplied by manufacturer for the six cheese samples

Cheese Name	Cheese Type	Age in Months (mo)	Fat (%)	Moisture (%)	Salt (%)	pH
Gouda	Gouda	One	30.50	41.88	1.86	5.14
Edam	Edam	Two	26.63	39.98	1.60	5.35
Cheddar 4mo	Cheddar	Four	33.90	37.81	2.01	5.21
Cheddar 8mo	Cheddar	Eight	34.77	35.70	1.70	5.32
Cheddar 15mo	Cheddar	Fifteen	32.77	37.43	1.95	5.02
Cheddar 32mo	Cheddar	Thirty two	33.23	37.75	1.89	5.24

2.2 Descriptive sensory analysis

Descriptive sensory analysis took place at the Department of Food Science, Stellenbosch University during the first two weeks of April 2010. The panel consisted of nine trained individuals with extensive descriptive sensory analysis experience. The panel was subjected to four training sessions. Training was conducted using the consensus method and analyses were performed according to "Generic Descriptive Analysis" described by Lawless and Heymann (2010).

The judges were trained using previously identified terminology for the sensory analysis of Cheddar cheese (Hort, Le Grys and Woodman, 1997; Murray and Delahunty, 2000; Drake *et al.,* 2001). Applicable sensory attributes and reference standards were obtained from published standards and lexicons to train the panel in Cheddar cheese flavour (Murray and Delahunty, 2000a; Drake *et al.,* 2001) and textural attributes of Cheddar cheese (Hort *et al.,* 1997). During the strining sessions, the attributes, definitions and reference standards from these lexicons were screened and modified by the panel for suitability. The agreed-upon terminology for this project consisted of three appearance, seven aroma, ten flavour and eight texture attributes, their corresponding definitions and reference standards. The attributes are listed in Tables 2, 3, 4 and 5. Drake *et al.* (2005) warns that the terms Cheddary, strength, balanced, maturity and aged are composite or meta-terms that are comprised of several more specific attributes. This makes it difficult to define or anchor from a lexicon perspective. The panel, however, felt that the terms lingering cheese flavour and Cheddar flavour adequately described the samples under investigation. The terms were retained with definitions and reference standards.

A 100 mm unstructured line scale with anchors of 0 and 100 at each end was used to measure attribute intensities. The scales increased in intensity from left to right for each attribute, the left-hand side of the scale corresponded to the lowest intensity and the right-hand side corresponded

to the highest intensity. Training sessions involved the panel members practicing the use of the continuous line scales, to develop their ability to repeatedly quantify the intensity of the different attributes.

Testing occurred over a period of two days. Three blocks of each cheese (1.5 x 4.5 x 4 cm), weighing approximately 10 g, were presented to each panel member in a covered glass ramekin. Each ramekin was labelled with a three-digit random code and presented in a randomised complete block design, balanced to minimise order and carry-over effects. All samples were removed from the fridge one hour prior to training and tempered to room temperature (approximately 19°C). Distilled water and water biscuits (Woolworths, South Africa) were provided as palate cleansers to avoid carry-over effects. Panel members were instructed to refresh their palates between samples. Cheeses were evaluated under standardised artificial white light, in individual tasting booths, dedicated to sensory analysis and free from external noise, aromas and distractions. Data were collected electronically using Compusense® *five* data collection software (Version 4.2; Compusense Inc., Guelph, Ontario, Canada).

Table 2 Appearance attributes with corresponding definitions for the six cheese samples.

Term	Definition
Appearance	
Glossy	The extent to which the surface is glossy / shiny *glossy - dull*
Visible white crystals	The extent to which white crystals are visible on the surface of the cheese *none - extreme*
Moisture seepage	The extent to which moisture is visible on the surface of the cut cheese *none - extreme*

Table 3 Aroma attributes with corresponding definition and reference standards for the six cheese samples (Scale ranged from 0=*None* to 100=*Extreme*).

Term	Definition	Reference standard
Aroma		
Cooked milk	The aromatics associated with cooked milk	Skimmed milk heated to 85°C for 30 min

Buttery	The aromatics associated with butter	Fresh unsalted butter
Creamy	The aromatics associated with fresh cream	Fresh cream
Sour cream	The aromatics associated with fresh sour cream	Fresh sour cream
Whey	The aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Brothy	The aromatics associated with boiled meat or vegetable stock	Bovril Spread
Cheddar	The aromatics associated with typical Cheddar cheese	Mild / Mature Cheddar cheese

Table 4 Flavour attributes with corresponding definitions and reference standards for the six cheese samples (Scale ranged from 0=*None* to 100=*Extreme*).

Term	Definition	Reference standard
Flavour:		
Creamy	Fatty, creamy tasting, of the nature of, or containing cream	Fresh cream
Caramel-sweet	The flavour associated with caramel sweets / topping	Nestle tinned caramel
Brothy	The flavour associated with boiled meat or vegetable soup stock	Bovril Spread
Lingering cheese	The overall intensity flavour, the degree of mildness and maturity	Mild / Mature Cheddar cheese
Cheddar	The flavour associated with typical Cheddar	Mild Cheddar
Prickle	The chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water
Sweet taste	The fundamental taste sensation elicited by sugars	Sucrose (5% in water)
Sour taste	The fundamental taste sensation elicited by acids	Citric acid (0.8% in water)
Salty taste	The fundamental taste sensation elicited by salts	Sodium chloride (0.5% in water)
Bitter	The fundamental taste sensation elicited by caffeine, quinine	Caffeine (0.8% in water)

Table 5 Texture attributes and corresponding definitions for the six cheese samples.

Term	Definition
Texture	
Creaminess	The extent to which the cheese has a velvety mouthfeel *not very creamy – very creamy*
Springiness	The extent to which the cheese springs back when compressed *not springy – very springy*
Rubberyness	The extent to which the sample pushes back against the molars during chewing *not rubbery – very rubbery*
Firmness	The force required to compress the cheese with the fingers *soft – firm*
Hardness	The force required to penetrate the cheese with a knife or the teeth *not very hard – very hard*
Crumbliness	The extent to which the sample breaks when chewed or compressed *not crumbly – very crumbly*
Graininess	The extent to which the cheese is bitty towards the end of chewing *not grainy – very grainy*
Teeth coating or stickiness to teeth	The degree to which the sample sticks to the molars during chewing *not sticky to very sticky*

2.3 Statistical procedures

Analysis of variance (ANOVA) with means separation was conducted to evaluate panel consistency across replicates of the same cheese. The data were analysed using SAS® software (Version 9; SAS Institute Inc, Cary, USA). Student's t-least significant difference (LSD) was calculated at the 5% significance level to compare treatment means. Pearson's correlation analysis was conducted to determine whether linear relationships existed between sample attributes.

3. RESULTS AND DISCUSSION

Results of the descriptive sensory analysis detailing appearance, aroma, flavour and texture attributes of the six cheese samples is summarised in the following paragraphs. ANOVA results for each attribute are listed in Tables 6, 7, 8 and 9.

3.1 Cheese composition

The cheese samples varied in age from 1 month to 32 months. The two younger cheeses, Gouda and Edam, were characterised by a glossy appearance, sour cream, creamy, buttery and cooked milk aromas, and creamy flavour, typical of those attributes found in young cheeses (Drake *et al.,* 2001; Young *et al.,* 2004). As the cheese samples matured, visible white crystals and moisture seepage became apparent; brothy and Cheddar aromas, as well as caramel sweet, brothy, lingering cheese, Cheddar and prickle flavours developed. Analysis of the texture attributes revealed that creaminess, springiness and rubberyness described the younger cheeses, while higher intensities of firmness, hardness, crumbliness, graininess and teethcoating were identified in the older cheese samples. Of interest, however, was the aroma and flavour characterisation of the 8 and 15 month Cheddar cheese samples. The 8 month Cheddar sample was characterised by aroma and flavour intensity levels similar to that of Cheddar at 32 months, while the 15 month sample was characterised by flavour intensities typically identified in a younger cheese. It is presumed that this phenomenon is linked to cheese composition, specifically moisture content and final pH.

It is likely that moisture content contributed to the more advanced aged flavours identified in the 8 month matured Cheddar cheese sample. Carunchia-Whetstine, Luck, Drake, Foegeding and Gerard (2007) reported that moisture content influenced protein hydrolysis and consequently flavour development. In cheese areas where moisture content was lower, protein hydrolysis was higher and resulted in greater intensities of aged flavours compared with higher moisture areas, reduced protein hydrolysis and greater intensities of younger flavours. Both the Gouda and Edam cheeses with moisture contents of 41.88% and 39.98%, respectively, were characterised by sour cream, buttery, creamy and cooked milk aromas and creamy, salty and slightly sour flavours. These flavours are typical of a young cheese (Drake *et al.,* 2001; Young *et al.,* 2004). With a moisture content of 35.70%, the 8 month old Cheddar cheese developed aromas and flavour intensities similar to that of the 32 month matured Cheddar cheese. Both cheeses were characterised by higher levels of whey and brothy aromas, and caramel sweet, brothy, lingering cheese, Cheddar and prickle flavours.

It is also likely that final pH contributed to the delay in flavour development of the 15 month old Cheddar cheese. This sample had the lowest pH of the four Cheddar cheeses. The activity of the ripening enzymes and their subsequent contribution to proteolysis may have been impeded at the lower pH (McSweeney, 2007; Personal communication with Ulf Mortensen, Application Manager, Innovation Cheese, Chr-Hansen A/S. dkumo@chr-hansen.com. 2012) which resulted in aged flavours developing at a slower rate than would have been expected for a 15 month mature Cheddar cheese.

The influence of fat content on the advanced aged flavours identified in the 8 month Cheddar cheese is doubtful. Although this sample had the highest fat content of all the samples at 34.77%, most of the reactions that create flavour compounds during aging are enzymatic and take place in

the aqueous phase (McSweeney and Fox, 2004). The most important function of fat is to dissolve and hold flavour components (Singh, Drake, and Cadwallader, 2003). Furthermore, Adda, Gripon and Vassal (1989) suggest that while fat content plays an important role in texture development, increasing the content in Cheddar cheese above a certain level could result in a higher frequency of off-flavours developing.

Salt content does not seem to have influenced flavour development in the six samples. Although McSweeney (2007) states that salt plays a major, albeit indirect role, on the hydrolysis of the caseins by chymosin, influences microbial growth and enzyme activity and contributes to the savoury flavour of cheese, the level of salt in the six samples does not seem to have contributed to the unusual flavour development in the 8 and 15 month matured cheese. Cheddar at 8 and 32 months had the same salt intensity, however, Cheddar at 8 months had 1.7% salt and Cheddar at 32 months had 1.89% salt. Edam and Cheddar at 4 months received the lowest and highest percentage readings for salt content at 1.6% and 2.01% respectively; however, their salty taste was not significantly different from one another (refer to Table 8).

Investigation of the correlation values ($p<0.05$) revealed few relationships between cheese sample composition and sensory attributes. Fat content was negatively correlated with buttery aroma ($r = -0.963$), creamy aroma (-0.973) and rubberyness ($r = -0.983$). The creamy and buttery attributes are generally the result of metabolism by lactic acid bacteria (Curioni and Bosset, 2002; McSweeney and Fox, 2004), thus, a reduction in fat would not necessarily influence creamy and buttery attributes. Moisture content correlated negatively with hardness ($r = -0.955$). This is clarified by Lawrence *et al.* (2004), who explain that higher moisture content is generally associated with a less rigid cheese matrix, which in turn, influences springiness and cohesiveness.

3.2 Appearance attributes

ANOVA results determined significant differences between the treatment means for all of the appearance attributes at a significance level of 5%. The mean sensory attribute scores for appearance and their least significant difference for the six samples of cheese are listed in Table 6. The attributes of glossy appearance, visible white crystals and moisture seepage differentiated the six cheese samples by age. A progressive decrease in glossy appearance was observed as the cheeses matured. Neither visible white crystals nor moisture seepage was evident in the three younger cheeses. Visible white crystals, however, were apparent and at the same intensity in the 8 and 15 month old Cheddar cheese samples. The intensity of this attribute increased to its highest level in the 32 month old cheese. Moisture seepage remained at the same intensity level for the Cheddar samples at 8, 15 and 32 months of age.

Table 6 Intensity means for appearance attributes of the six cheese samples.

	Glossy	Visible white crystals	Moisture seepage
Treatment	[2] Mean	[2] Mean	[2] Mean
Gouda	38.24[a]	0.28[c]	0.00[b]
Edam	30.99[b]	0.00[c]	0.00[b]
Cheddar 4mo	17.10[c]	0.35[c]	0.71[b]
Cheddar 8mo	10.72[d]	11.33[b]	16.76[a]
Cheddar 15mo	10.13[d]	12.65[b]	16.17[a]
Cheddar 32mo	10.50[d]	19.91[a]	19.24[a]
[1] LSD	**2.49**	**3.91**	**3.15**

[1] Least Significant Difference (p=0.05)

2 Values with the same superscript are not significantly different

3.2.1 Glossy

Glossy appearance describes the extent to which the surface of a cheese is glossy and was measured from glossy to dull. Intensity scores ranged from 10.13 to 38.24 (Table 6). The attributed differentiated the samples by age. A progressive decrease in glossy appearance was observed as the cheeses aged and evident in Figure 1. Gouda at 1 month of age received the highest score for the glossy attribute followed Edam at 2 months of age. Results for Cheddar at four months fell mid-way between the two younger cheeses and those of the three older cheeses. The three oldest Cheddar samples were characterised as having the same intensity of the attribute glossy ($p>0.05$). These results suggest that a glossy appearance describes the surface of a younger cheese, while the surface of the older cheeses would be more appropriately described as dull.

Investigation of the correlation values ($p<0.05$) revealed a strong positive correlation with creamy flavour ($r = 0.943$), which is normally associated with the flavour development of a younger cheese (Drake et al., 2001; Drake et al., 2002); springiness ($r = 0.991$) and moisture ($r = 0.937$).

3.2.2 Visible white crystals

The attribute visible white crystals describes the extent to which white crystals are visible on the surface of the cheese and was measured from none to extreme. Intensity scores ranged between 0.00 and 19.91, indicating that the attribute was not apparent on all of the cheeses and where evident, at low levels (Table 6; Figure 2). White crystals were not obvious in the younger cheeses;

however, they became apparent as the cheeses aged. Cheddar at 32 months received the highest score for visible white crystals ($p<0.05$), while scores for Cheddar at 8 and 15 months were slightly lower. The latter results, however, were not significantly different from one another ($p>0.05$).

Investigation of the correlation values indicated significant positive correlations with Cheddar aroma (0.931), sweet ($r = 0.928$), caramel sweet ($r = 0.923$), bitter ($r = 0.969$), brothy flavour ($r = 0.919$), lingering cheese flavour ($r = 0.915$) and prickle ($r = 0.914$). These attributes are generally associated with the flavour development of an aged cheese (Drake *et al.*, 2001; Drake *et al.,* 2002). Further positive correlations were found with graininess ($r = 0.973$), teethcoating ($r = 0.931$) and moisture seepage ($r = 0.968$). These results suggest that the appearance of white crystals on the surface of a cheese is associated with the age.

Observable white crystals on the surface of a cheese are considered a quality defect (Chou, Edwards, Luedecke, Bates and Clark, 2003). Rajbhandari and Kindstedt (2005) identified the crystals as calcium lactate pentalhydrate, calcium and lactate being the principal components (Agarwal, Powers, Swanson, Chen and Clark, 2006). The crystals form when calcium and lactate ions exceed their solubility, supersaturate in the serum phase of the cheese and crystallize at nucleation sites (Rajbhandari and Kindstedt, 2005). It has been proposed by Swearingen, Adams and Lensmire (2004) and Agarwal *et al.* (2006) that certain non-starter lactic acid bacteria convert L(+)-lactate into a racemic mixture of L(+)-lactate and D(-)-lactate. D(-)-lactate is less soluble than L(+)-lactate, and thus more prone to crystallization. Factors which favour crystallisation include high lactose levels in milk (Kubantseva, Hartel, and Swearingen, 2004), certain starter culture strains (Swearingen *et al.*, 2004), contamination of cheese by non-starter lactic acid bacteria (Chou, *et al.,* 2003), low storage temperature (Chou, *et al.*, 2003), storage temperature fluctuations (Kubantseva *et al.*, 2004) and low salt in moisture levels (Swearingen *et al.*, 2004; Rajbhandari *et al.*, 2005).

3.2.3 Moisture seepage

Moisture seepage describes the extent to which moisture is visible on the surface of the cut cheese and was measured from none to extreme. Intensity scores ranged between 0.00 and 19.24, indicating that the attribute was not identified in all of the samples and at the lower end of the scale when it was present (Table 6). The attribute differentiated the cheeses by age, as evident in Figure 2. Moisture seepage was not observed in the three younger cheeses; however, it was apparent, but at no significant difference ($p>0.05$) in the Cheddar samples at 8, 15 and 32 months of age.

Positive correlations were identified for visible white crystals ($r = 0.968$), crumbliness ($r = 0.950$), graininess ($r = 0.999$) and teeth-coating ($r = 0.956$). These results further suggest that moisture seepage is associated with age.

Swearingen *et al.* (2004) also list moisture seepage as defect in the appearance quality of cheese. It has been proposed that weeping or the expulsion of free liquid from the surface of the cheese is

caused by the reduced water binding capacity of the paracasein (Swearingen *et al.,* 2004). Post-manufacture fermentation is believed to affect the calcium partitioning between the intact cheese paracasein (colloidal) and the serum, which leads to the expulsion of liquid (Swearingen *et al.*, 2004). Conversely, efforts to reduce weeping have been associated with the level of salt in moisture of cheese. Salt promotes the water binding capacity of the paracasein, thereby increasing the cheeses ability to hold moisture (Swearingen *et al.*, 2004).

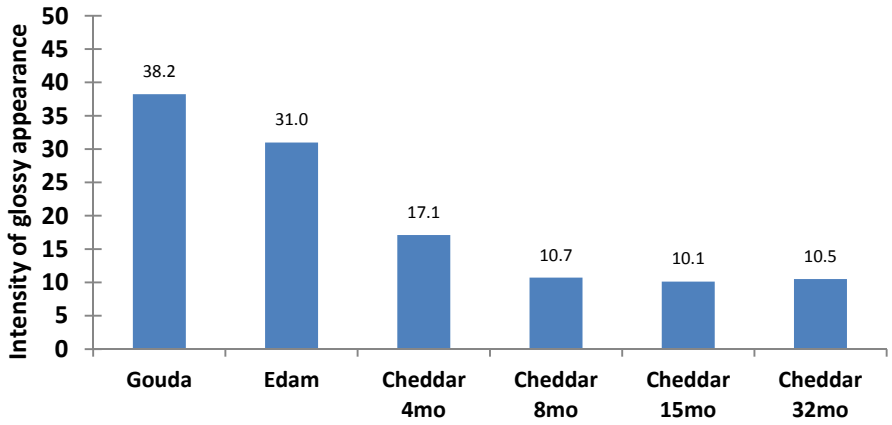

Figure 1 Mean intensity scores for glossy appearance as the cheese samples aged.

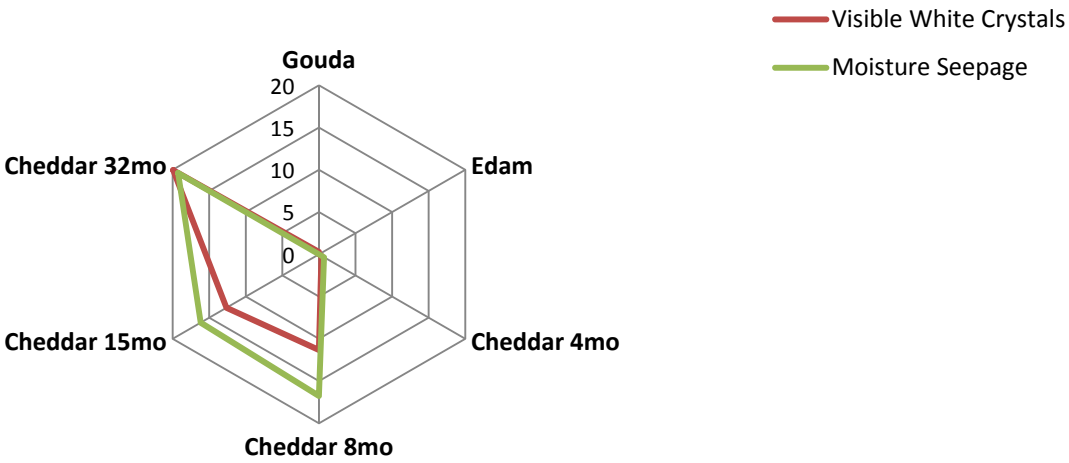

Figure 2 Characterisation and comparison of the visible white crystals and moisture seepage identified in the six cheese samples.

3.3 Aroma characterisation

ANOVA results determined significant differences between the treatment means for all of the aroma attributes at a significance level of 5%. The mean sensory attribute scores for aroma and their least significant difference for the six samples of cheese are listed in Table 7.

The seven aroma attributes characterised and differentiated the six cheese samples. No progressive development in any of the attributes was identified as the cheese samples aged. However, buttery and creamy aroma intensities were higher in the younger cheeses up to four months while brothy and Cheddar aroma intensities were higher in the older cheese samples. This is consistent with previous research (Drake *et al.*, 2001; Drake *et al.*, 2002; Young *et al.*, 2004). At one month, the Gouda was characterised by sour cream, buttery and creamy aroma (Figure 3). Edam at two months of age was described by creamy, buttery and cooked milk aroma (Figure 4). The Cheddar sample at four months was differentiated mainly by Cheddar aroma combined with creamy and buttery aroma (Figure 5). The three older Cheddar samples were characterised by Cheddar, brothy and sour cream aroma (Figure 6, 7 and 8). It is interesting to note, however, that although the Cheddar sample at 15 months was described by Cheddar and brothy aroma, intensities were lower than that of the 8 month Cheddar sample. Furthermore, creamy aroma in this sample was at the same intensity as the 4 month old Cheddar. This suggests that the 15 month old sample did not develop the aroma intensity that would have been expected from a cheese in this age category, while the sample at 8 months developed aged aroma intensities similar to that of a 32 month old cheese.

Table 7 Aroma intensity means of the six cheese samples.

	Cooked Milk	Buttery	Creamy	Sour Cream	Whey	Brothy	Cheddar
Treatment	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean
Gouda	2.37^{c}	18.32^{b}	17.30^{b}	32.38^{a}	4.10^{b}	0.25^{d}	0.27^{e}
Edam	11.89^{a}	33.71^{a}	41.83^{a}	7.33^{c}	3.75^{b}	0.00^{d}	0.00^{e}
Cheddar 4mo	10.11^{ba}	13.27^{c}	14.44^{cb}	6.06^{c}	3.36^{b}	11.60^{c}	20.45^{d}
Cheddar 8mo	3.18^{c}	6.13^{e}	10.75^{cd}	16.87^{b}	7.97^{a}	22.26^{a}	51.51^{b}
Cheddar 15mo	7.72^{b}	9.53^{d}	14.18^{cb}	15.87^{b}	4.58^{b}	18.48^{b}	44.14^{c}
Cheddar 32mo	2.65^{c}	6.80^{e}	10.08^{d}	16.12^{b}	7.56^{a}	24.66^{a}	57.82^{a}
[1] LSD	**2.54**	**2.18**	**4.09**	**2.83**	**2.31**	**2.43**	**4.01**

[1] Least Significant Difference (p=0.05)

[2] Values with the same superscript are not significantly different

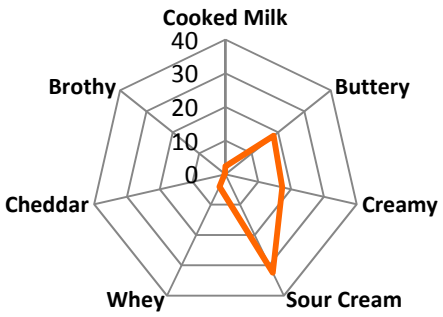

Figure 3 Aroma characterisation of Gouda cheese sample at 1 month in age.

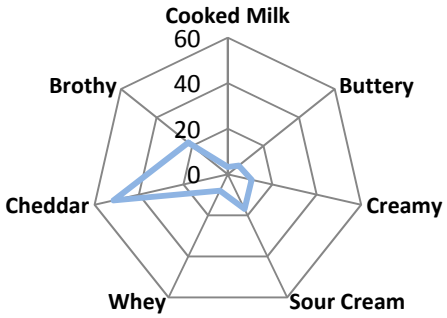

Figure 6 Aroma characterisation of Cheddar sample matured to 8 months.

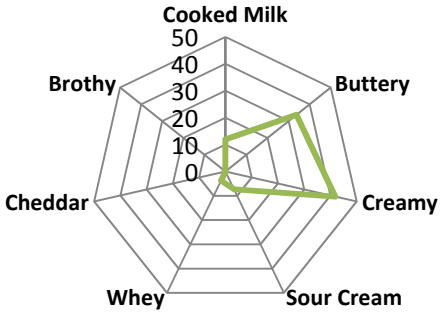

Figure 4 Aroma characterisation of Edam cheese sample at 2 months in age.

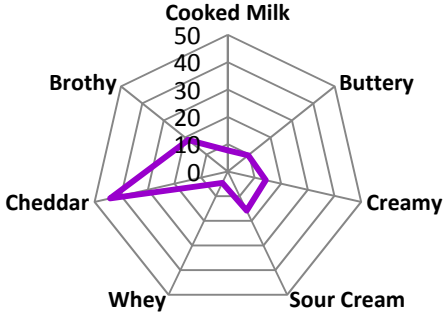

Figure 7 Aroma characterisation of Cheddar sample matured to 15 months.

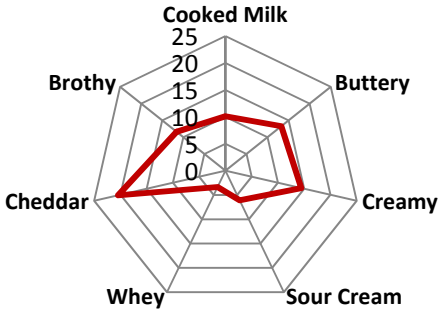

Figure 5 Aroma characterisation of Cheddar cheese sample at 4 months in age.

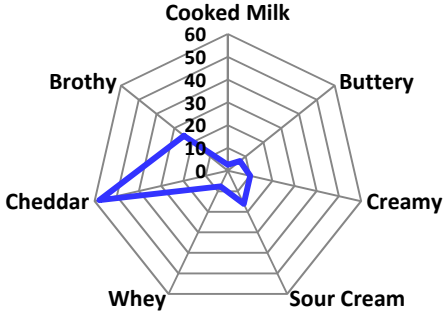

Figure 8 Aroma characterisation of Cheddar cheese matured to 32 months.

3.3.1 Cooked milk aroma

Mean intensity scores of the cooked milk attribute fell between 2.37 and 11.89 (Table 7), indicating that although present in the cheese samples, it was at a fairly low level. The highest level of cooked milk aroma was found in the Edam sample, while intensity levels in the Gouda, Cheddar at 8 months and Cheddar at 32 months were not significantly different from one another ($p>0.05$). It is generally expected that the intensity of this attribute will decrease as the cheese ages (Piggott and Mowat, 1991). However, in this study, intensity of cooked milk aroma increased in Cheddar at 15 months to a similar level of that in the Cheddar at 4 months (Figure 9). These results are inconsistent with previously documented observations, as this attribute generally describes the aromatics associated with younger cheeses (Drake *et al.*, 2001; Drake *et al.*, 2002; Young *et al.,* 2004). In this project, the attribute was perceived at the same level in a 1, 8 and 32 month old cheese.

The descriptor cooked milk odour has been linked to the chemical compounds 2-nonanone and methional (Curioni and Bossett, 2002). 2-Nonanone is a ketone and considered a common constituent of most dairy products, while methional typically originates from methionine degradation and results from the cleavage of a bond between carbon and sulphur (Curioni and Bossett, 2002). No significant correlations were identified between cooked milk aroma and any of the other attributes.

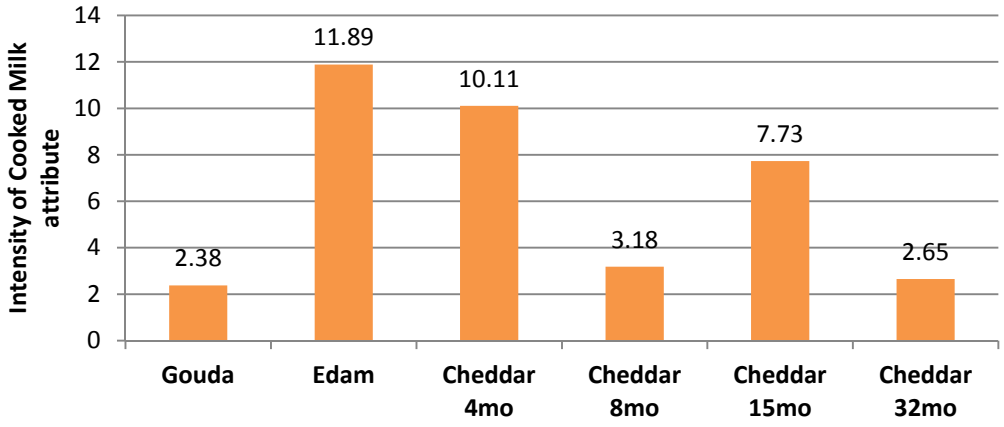

Figure 9 Intensity levels of cooked milk aroma as the cheese samples aged.

3.3.2 Buttery aroma

Mean intensity scores for the attribute buttery ranged between 6.13 and 33.71 (Table 7). The attributed differentiated the cheese samples by age as higher levels of buttery aroma were perceived in the three younger cheeses (Figure 10). This is consistent with published observations (Drake *et al.*, 2001; Drake *et al.*, 2002; Young *et* al., 2004). A progressive decrease occurred in the intensity of this attribute as the cheeses aged, with the 15 month old sample being an exception. As with cooked milk aroma, the intensity of buttery aroma increased in the 15 month

old cheese to a higher level than the 8 month old Cheddar cheese sample. The intensity of buttery aroma was, interestingly, at the same level in Cheddar at 8 months and Cheddar at 32 months ($p>0.05$). The chemical compound commonly associated with buttery aroma is 2,3-butanedione or diacetyl (Curioni and Bossett, 2002; Zehentbauer and Reineccius, 2002; Frank, Owen and Patterson, 2004). Diacetyl is obtained from pyruvate which originates from lactose and citrate metabolism by lactic acid bacteria (Curioni and Bossett, 2002). This is consistent with one of the negative correlations established between buttery aroma and fat ($r = -0.963$), since the highest level of this attribute was identified in the reduced fat cheese, suggesting that fat content does not necessarily contribute to buttery aroma.

Investigation of the correlation values ($p<0.05$) identified a significantly positive relationships with creamy aroma ($r = 0.969$), rubbery texture ($r = 0.972$) and a further negative correlation with sour ($r = -0.974$).

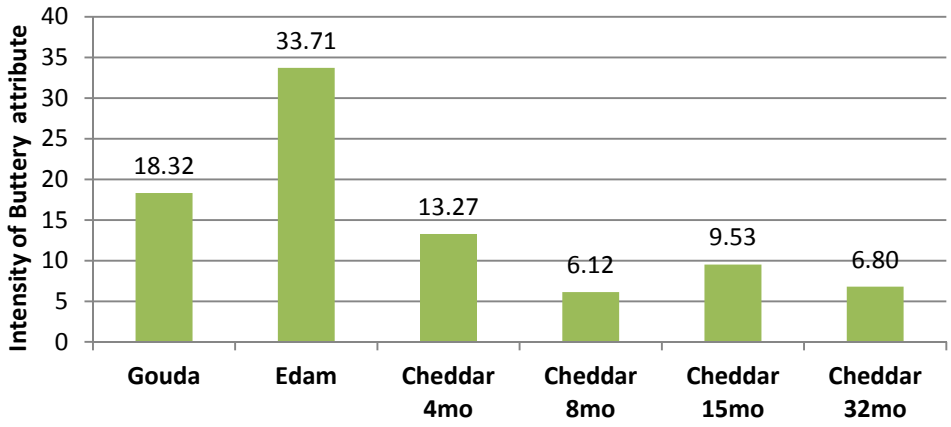

Figure 10 Intensity levels of buttery aroma as the cheese samples aged.

3.3.3 Creamy aroma

Mean intensity scores for creamy aroma ranged between 10.08 and 41.03 (Table 7). The highest level of creamy aroma was identified in the Edam at 2 months of age. Creamy aroma dropped significantly in the Gouda. Again the intensity of this attribute was at similar levels in the Cheddar at 4 and 15 months of age ($p>0.05$), indicating again that the flavour development of the older cheese was in some way delayed. The attribute was at its lowest levels in the Cheddar at 8 and 32 months respectively (Figure 11). Results from this experiment are inconsistent with those previously observed, as the creamy attribute is generally found in younger cheeses (Drake *et al.*, 2001; Young *et al.*, 2004) and its intensity, according to Muir, Hunter, Banks and Horne (1996) should decrease systematically over time.

Walstra *et al.* (2006) state that on heating, some fatty acids exhibit chemical reactions. 4- and 5-hydroxy fatty acid residues give rise to γ- and δ-lactones. These are present in fresh milk and are partly responsible for the characteristic flavour and aroma of milk fat. The aroma descriptor creamy is associated with the chemical components δ-decalactone (Curioni and Bossett, 2002), δ-

dodecalactone (Drake, Miracle, and McMahon, 2010) and (*Z*)-4-hepetnal (Zehentbauer and Reineccius, 2002). Although the lactones are generally associated with pronounced peach, apricot and coconut odour qualities, in cheese, it is believed that the lactones are generated by hydrolysis of hydroxyl-fatty acid triglycerides (normal constituents of milk fat), followed by lactonisation (Curioni and Bossett, 2002) and could possibly be perceived as creamy.

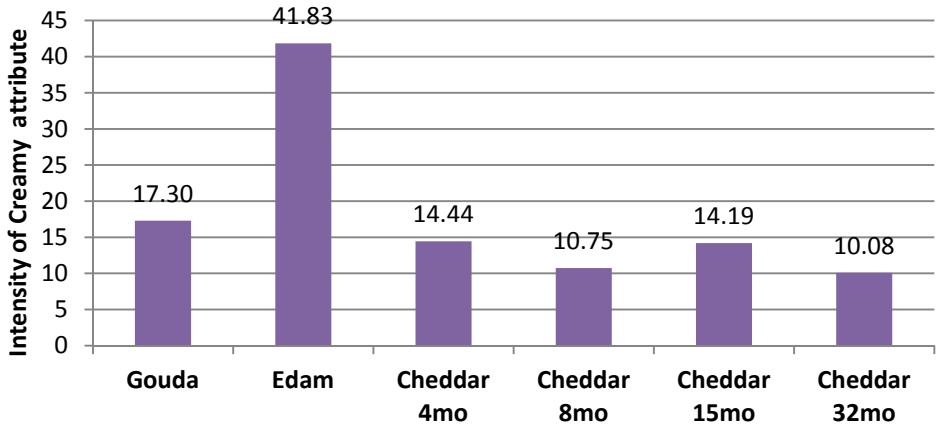

Figure 11 Intensity levels of creamy aroma as the cheese samples aged.

3.3.4 Sour cream aroma

Mean intensity scores for sour cream aroma ranged between 6.06 and 32.38 (Table 7). The attribute did not differentiate the samples by age and neither was there a steady progression in the attribute as the samples aged (Figure 12). An interesting pattern, however, was observed. Gouda at 1 month received the highest score for this attribute. Edam and 4 month old Cheddar were perceived as having the same level of sour cream aroma, however, this was at a significantly lower level than the Cheddar at 8, 15 and 32 months of age ($p<0.05$). Sour cream aroma is generally associated with younger cheeses (Drake *et al.,* 2001; Young *et al.*, 2004)

3-hydroxy-2-butanone, a ketone, is the chemical compound frequently associated with the aroma sour cream (Curioni and Bossett, 2002). O'Riordan and Delahunty (2001) identified heptanal as the component corresponding to the sour milk/dairy descriptor.

Investigation of the correlation values ($p<0.05$) only identified a positive relationship with salty taste ($r = 0.963$), suggesting that as the intensity of sour cream aroma increased, so too did the perception of salty taste.

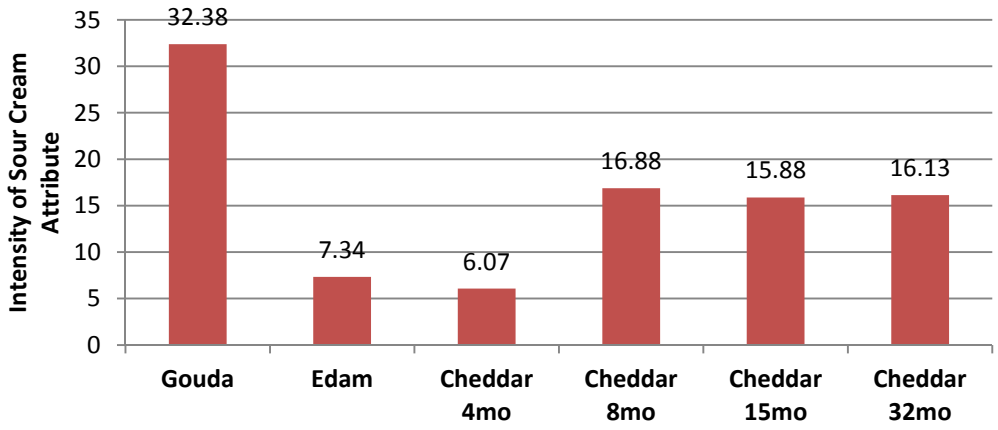

Figure 12 Intensity levels of sour cream aroma as the cheese samples aged.

3.3.5 Whey aroma

Mean intensity scores for whey aroma fell between 3.36 and 7.97 indicating that although perceived in the cheese samples, it was at low levels (Table 7). This attribute is generally associated with young and undeveloped flavours (Drake *et al.,* 2001 and Young *et al.,* 2004). However, in this study it was perceived at higher levels in the 8 and 32 month old Cheddar samples. Results for whey aroma were the same for the remaining four cheese samples ($p>0.05$), suggesting again that the 15 month old sample did not develop aroma intensities expected of a Cheddar cheese at this age (Figure 13).

Investigation of the correlation values ($p<0.05$) revealed a positive correlation between bitter taste ($r = 0.926$). The reason for this correlation is unclear and needs to be investigated further.

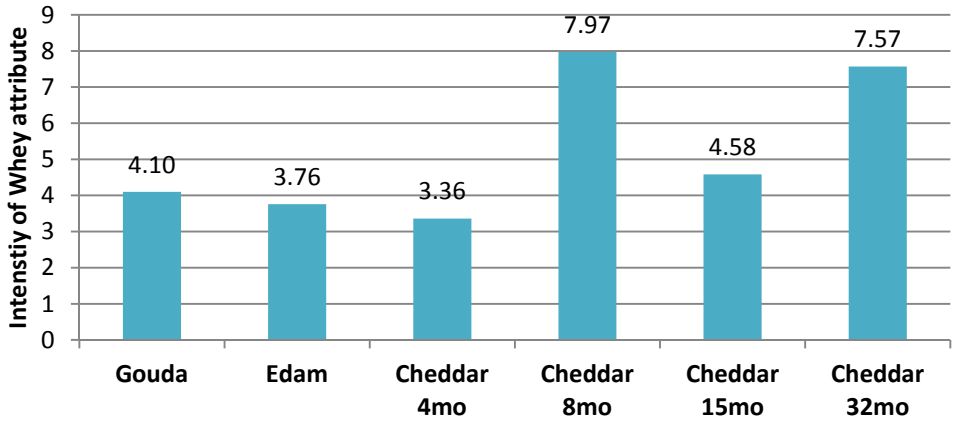

Figure 13 Intensity levels of whey aroma as the cheese samples aged.

3.3.6 Brothy aroma

The mean intensity scores for brothy aroma ranged between 0 and 24.66 indicating that the attribute was not found in all of the cheese samples (Table 7). Brothy aroma differentiated the cheese samples by age as higher intensities were identified in the three older Cheddar cheeses and nothing in the younger cheeses. A progressive increase in intensity was observed as the cheeses aged (Figure 14). This is consistent with research conducted previously by Drake *et al.* (2001) and Young *et al.* (2004). Again the intensity of brothy aroma found in the sample of Cheddar at 15 months presented was significantly lower ($p<0.05$) than that of Cheddar at 8 months and Cheddar at 32 months. This suggests that the intensity of this aroma did not fully develop and was not at the level expected of a 15 month old Cheddar cheese.

The brothy aroma attribute has been associated with the chemical components 2-methyl-fuanthiol (Smit, Smit and Engels, 2005; Carunchia-Whetstine *et al.*, 2006), methional, furaneol and 2-methyl-3-furanthiol (MFT) (Cadwallader *et al.*, 2006) and dimethyl ethyl pyrazine (Frank, Owen and Patterson, 2004).

Investigation of the correlation values ($p<0.05$) revealed a number of positive relationships with flavour attributes generally identified in aged cheese (caramel sweet r = 0.972; sour r = 0.914; bitter r = 0.912; brothy flavour r = 0.963; lingering cheese flavour r = 0.996; Cheddar flavour r = 0.988 and prickle r = 0.980), which is consistent with results published by Drake *et al.* (2001) and confirms that brothy aroma is generally associated with aged cheese flavours.

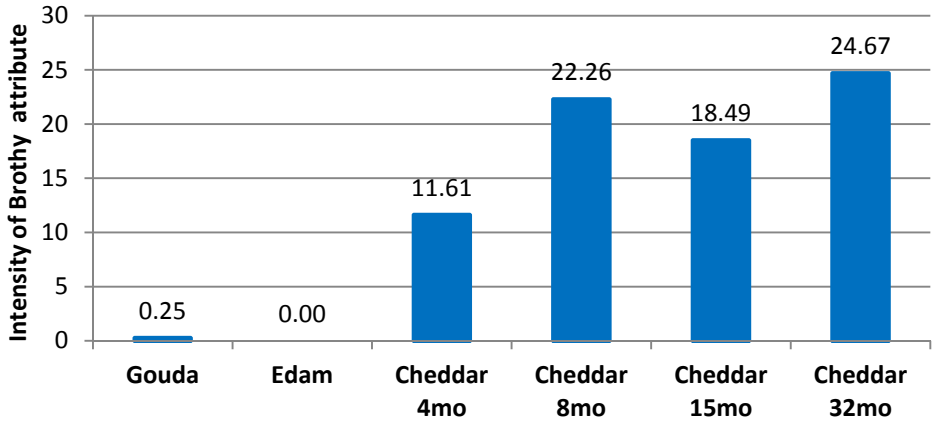

Figure 14 Intensity levels of brothy aroma as the cheese samples aged.

3.3.7 Cheddar aroma

Mean intensity scores for the attribute Cheddar aroma fell between 0 and 57.82 indicating that the attribute was not present in all cheese samples (Table 7). Cheddar aroma differentiated the cheese samples by age and a progressive increase was identified as the cheeses aged (Figure 15). Neither the Gouda at 1 month nor the Edam at 2 months presented any Cheddar aroma intensity. Again, the intensity of this attribute in the Cheddar at 15 months was lower than in

Cheddar at 8 months. Cheddar matured to 32 months, however, was characterised by the highest level of Cheddar aroma. Ethyl hexanoate, butanoic acid and decanoic acid are chemical compounds that have been associated with Cheddar aroma (Curioni and Bossett, 2002). Drake *et al.* (2010) associated butyric acid, 2-methyl butyric acid and 3-methyl butyric acid with Cheddar aroma.

Strong positive relationships were identified between Cheddar aroma and brothy aroma (r = 0.994), lingering cheese flavour (r = 0.998), Cheddar flavour (0.995) and prickle (r 0.991) suggesting that Cheddar aroma is associated with aged cheese flavours. Additional relationships were identified between Cheddar aroma and aged cheese attributes of visible white crystals (r = 0.931), moisture seepage (r = 0.961), caramel-sweet (r = 0.974), firmness (r = 0.973) and crumbliness (r = 0.984). Glossy appearance (r = -0.930), creamy flavour (r = -0.987) and springiness (r = -0.948) correlated negatively with Cheddar aroma, again suggesting that higher intensities of Cheddar aroma describe an aged cheese.

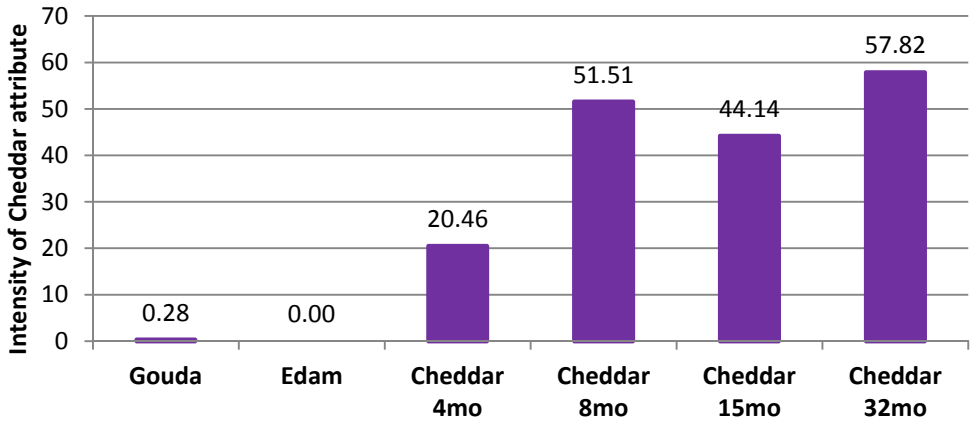

Figure 15 Intensity levels of Cheddar aroma as the cheese samples aged.

3.4 Flavour characterisation

ANOVA results determined significant differences between the treatment means for all of the flavour attributes at a significance level of 5%. The mean sensory attribute scores for flavour and their least significant difference for the six samples of cheese are listed in Table 8.

Ten flavour attributes differentiated and characterised the six cheese samples. Flavour development, however, was inconsistent as the cheese samples aged. Gouda and Edam at 1 and 2 months, respectively, were characterised as creamy, salty, and slightly sour with a lingering cheese flavour (Figure 16 and 17). Cheddar at 4 months was described as creamy with a lingering cheese and Cheddar flavour; salty, sour and slightly sweet taste (Figure 18). At 8 months (Figure 19), the Cheddar sample showed flavour development and characterization similar to that of a 32 month old Cheddar cheese. Intensity levels for sour taste, salty taste, brothy, lingering cheese,

Cheddar and prickle flavours were significantly the same as those of the 32 month old cheese. This would indicate that flavour development may have been enhanced through exposure to higher ripening temperatures or through the addition of adjunct cultures (Grazier, 1992; Law, 2010). Moisture content may also have influenced flavour development. The Cheddar cheese at 8 months had the lowest moisture and Carunchia-Whetstine (2007) suggests that low moisture content contributes to higher levels of protein hydrolysis and consequently higher intensities of aged flavours developing. Alternatively, the flavour development of the 15 month sample (Figure 20), did not develop as expected. Creamy flavour, generally identified in a young cheese (Drake *et al.*, 2001), was identified at a lower level than that in the Cheddar cheese at 4 months, but at a significantly higher level than both Cheddars at 8 and 32 months. Intensity levels for caramel-sweet, brothy, lingering cheese, Cheddar and prickle flavours for this sample were significantly lower than the 32 month old Cheddar sample. This would indicate that the flavour development of the 15 month old sample fell midway between that of the 4 and 8 month old Cheddar sample and did not present flavours typical of a mature cheese. This delayed flavour development may have been a result of the lower final pH 5.02 in the Cheddar at 15 months. A lower pH can influence the activity of the enzymes involved in ripening and their subsequent contribution to proteolysis and flavour development (McSweeney, 2007, Ulf Mortensen, Application Manager, Innovation Cheese, Chr-Hansen A/S. dkumo@chr-hansen.com. 2012). The oldest Cheddar, at 32 months of age was predominantly described by Cheddar and lingering cheese flavour (Figure 21). Flavour attributes of creamy, prickle, brothy and the three basic tastes, salty, sweet, and sour also contributed to the characterisation of this cheese.

Table 8 Intensity means for the flavour attributes of the six cheese samples.

	Sweet	Sour	Salty	Bitter	Creamy	Caramel-Sweet	Brothy	Lingering Cheese	Cheddar	Prickle
Treatment	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean
Gouda	16.40^{dc}	16.78^{b}	44.93^{a}	0.41^{d}	52.12^{a}	0.48^{de}	0.13^{d}	16.64^{d}	0.00^{d}	0.00^{d}
Edam	18.50^{c}	10.31^{c}	25.41^{d}	0.00^{d}	53.54^{a}	0.30^{e}	0.00^{d}	18.77^{d}	0.14^{d}	0.00^{d}
Cheddar 4mo	13.31^{d}	24.70^{a}	26.88^{cd}	0.38^{d}	42.90^{b}	2.30^{dc}	5.56^{c}	34.40^{c}	29.43^{c}	7.63^{c}
Cheddar 8mo	20.62^{bc}	28.24^{a}	30.61^{b}	6.77^{b}	29.86^{d}	5.28^{ba}	26.70^{a}	56.55^{a}	59.30^{a}	27.12^{a}
Cheddar 15mo	23.87^{ba}	25.18^{a}	29.00^{cb}	4.41^{c}	33.79^{c}	3.45^{bc}	21.36^{b}	48.65^{b}	51.92^{b}	20.34^{b}
Cheddar 32mo	27.70^{a}	26.62^{a}	30.95^{b}	8.92^{a}	31.77^{dc}	6.52^{a}	24.75^{a}	60.48^{a}	63.41^{a}	25.94^{a}
[1] LSD	**4.26**	**3.57**	**3.00**	**1.70**	**2.67**	**1.92**	**2.44**	**4.32**	**5.03**	**3.22**

[1] Least Significant Difference (p=0.05)

[2] Values with the same superscript are not significantly different

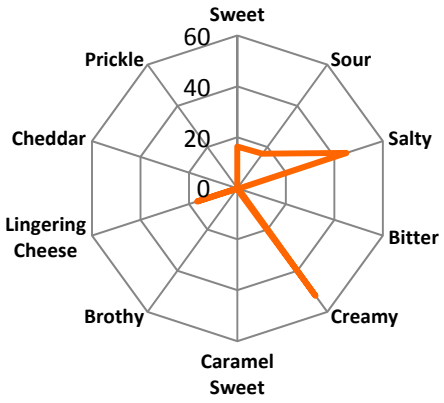

Figure 16 Flavour characterisation of the Gouda cheese sample at 1 month of age.

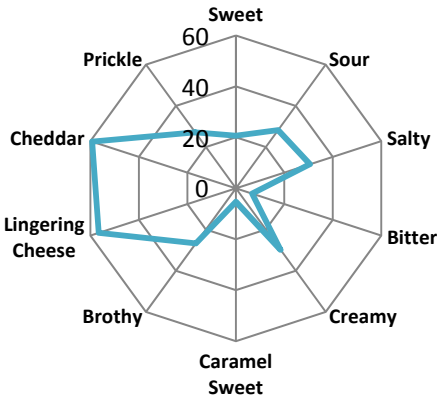

Figure 19 Flavour characterisation of the Cheddar sample at 8 months of age.

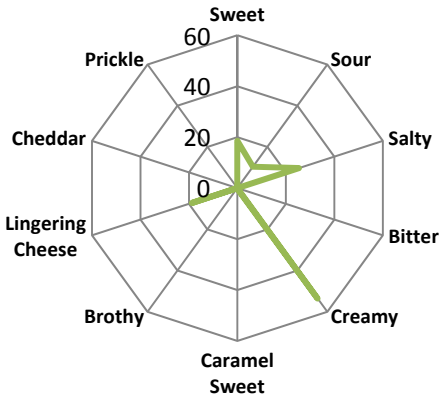

Figure 17 Flavour characterisation of the Edam cheese sample at 2 months of age.

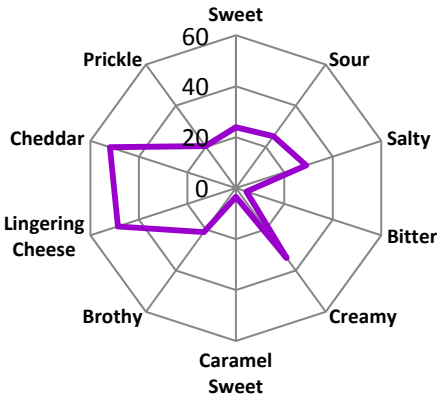

Figure 20 Flavour characterisation of the Cheddar sample at 15 months of age.

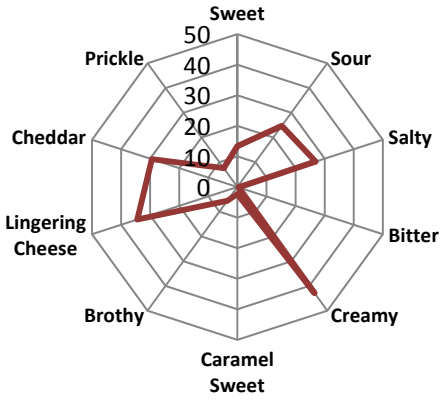

Figure 18 Flavour characterisation of the Cheddar sample at 4 months of age.

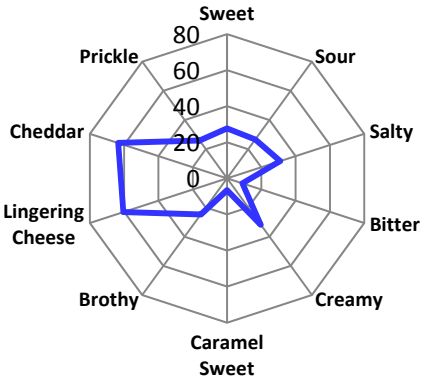

Figure 21 Flavour characterisation of the Cheddar sample at 32 months of age.

3.4.1 Sweet taste

Mean intensity scores for the attribute sweet fell between 13.31 and 27.27, indicating that although perceivable, it was not at an elevated level (Table 8). The highest concentration of sweet taste was identified in 32 month old Cheddar, while the 4 month old Cheddar cheese received the lowest score. A progressive increase in sweet taste became evident in the Cheddar cheese samples from 4 months (Figure 22). Edam at 2 months had a slightly higher level of sweetness than Gouda although this difference was not significant ($p>0.05$).

Investigation of the correlation values ($p<0.05$) revealed only one significant relationship with visible white crystals ($r = 0.928$). This result suggests that higher levels of sweet taste identified in cheese may be associated with the appearance of white crystals. It is interesting to note that the primary components of the crystals are calcium, from the cheese milk and lactate, from lactose fermentation (Agarwal *et al.*, 2006). McSweeney (1997), however, argues that sweet taste frequently applies to a lack of acidity in cheese and not necessarily the presence of lactose, glucose or galactose sugars. Furthermore, the sweet taste associated with cheese originates from the breakdown of proteins during the maturation process (McSweeney, 2007). Lawlor *et al.* (2002) found a positive correlation between sweet taste in cheese and concentrations of individual free amino acids (arginine, threonine, isoleucine, histidine, serine and proline). In addition, Robinson and Wilbey (1998) note that the amino acids serine and proline have a distinctive sweet taste. Manipulation of ripening temperature, according to Grazier *et al.* (1991), can also influence the intensity of sweet taste in a cheese.

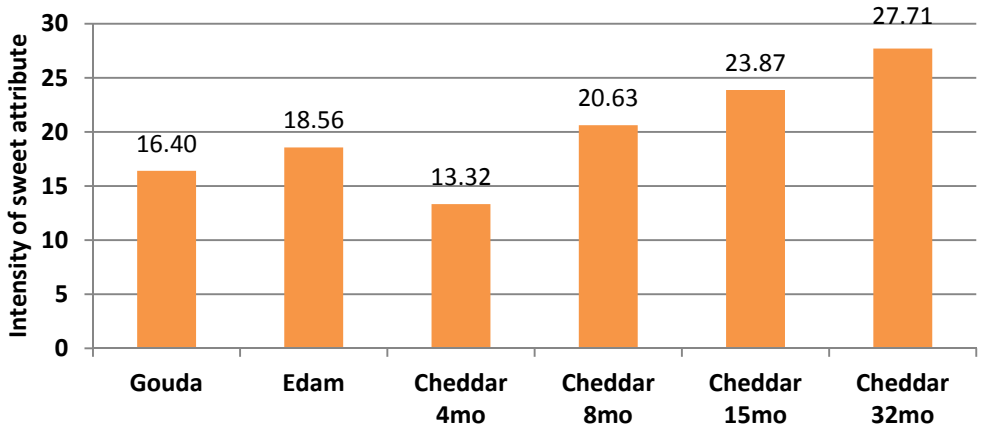

Figure 22 Intensity levels of sweet taste as the cheese samples aged.

3.4.2 Sour taste

Mean intensity scores for the attribute sour ranged from 10.31 to 28.24, indicating that although sour taste was perceivable in the samples, it was not at a high level (Table 8). Edam, at 2 months of age received the lowest rating for sour taste, while Cheddar at 8 months received the highest level. A progressive increase in sour taste was detected in the Cheddar cheeses, however, there was no significant difference between the four samples (Figure 23). This corresponds with Muir *et al.* (1996) who suggest that a progressive increase in acid taste is a core change associated with the ripening of cheese.

Investigation of the correlation values ($p<0.05$) revealed positive correlations with brothy aroma ($r = 0.914$), Cheddar flavour ($r = 0.911$), firmness ($r = 0.919$) and fat content ($r = 0.955$). Brothy aroma and Cheddar flavour are often associated with aged and mature flavours while buttery and creamy aroma, as well as creamy flavour are associated with young and undeveloped flavours (Drake *et al.*, 2001; Drake *et al.*, 2002). These results suggest that sour taste was more prominent in the aged cheeses and not identified at high levels in the young cheeses. It is also worth noting that these results indicate that sour taste would be more noticeable in a cheese with higher levels of fat. Cheddar at 8 months maturity did indeed have the highest recorded fat content of 34.77%. Literature suggests that it is lactic acid (McSweeney, 1997) and acetic acid (Grazier, 1992) that contribute to the overall sour taste in cheese. Grazier (1992) further comments that sour taste is a function of ripening temperature and most readily noted during the early stages of ripening.

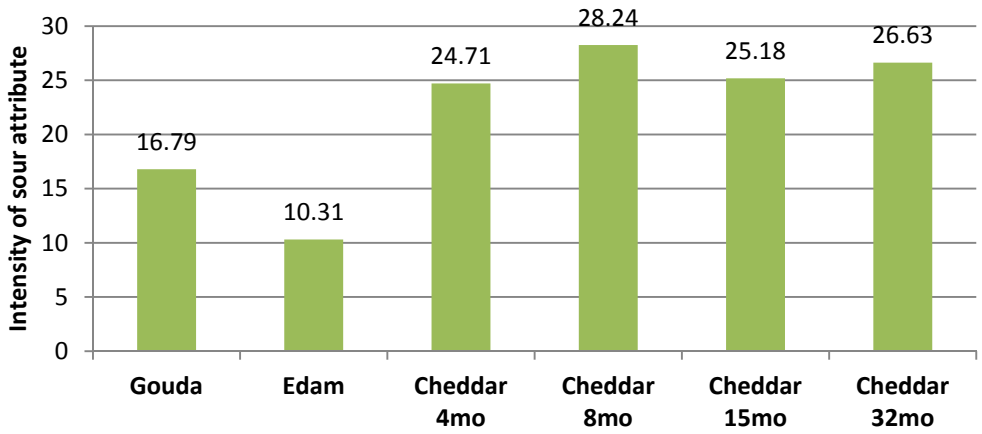

Figure 23 Intensity levels of sour taste as the cheese samples aged.

3.4.3 Salty taste

Mean intensity scores for salty taste ranged from 25.41 to 44.93 indicating a slightly higher intensity of this taste in the cheese samples than both sweet and sour (Table 8). Gouda, the youngest cheese, received the highest score for salty taste. It is interesting to note that Gouda did not have the highest level of compositional salt. Cheddar at 8 and 32 months of age, respectively were not significantly different from one another. Furthermore, Cheddar at 4 and 15 months were also not significantly different from one another ($p>0.05$). This would suggest that the four and 15

month old cheese had the same level of salty taste. Edam, a two month old cheese, had the lowest perceived saltiness. This corresponds with the compositional 1.60% salt level, the lowest of the six cheeses. No progressive increase in salty taste was identified as the cheeses aged (Figure 24). This is contrary to Muir *et al.* (1996), who noted progressive changes in the salt taste of cheese over a 12 month period. McSweeney (1997), however, suggests that variations in the salty taste of a cheese are likely to be related to processing parameters such as the amount of salt added and its distribution throughout the cheese. O'Mahony, Sheehan, Delahunty and McSweeney (2006) comment that salt is an important component of background flavour and not necessarily a flavour component that discriminates between cheeses. Investigation of the correlation values ($p<0.05$) revealed a positive correlation for salty taste with sour cream aroma ($r = 0.963$) and creamy texture ($r = 0.965$).

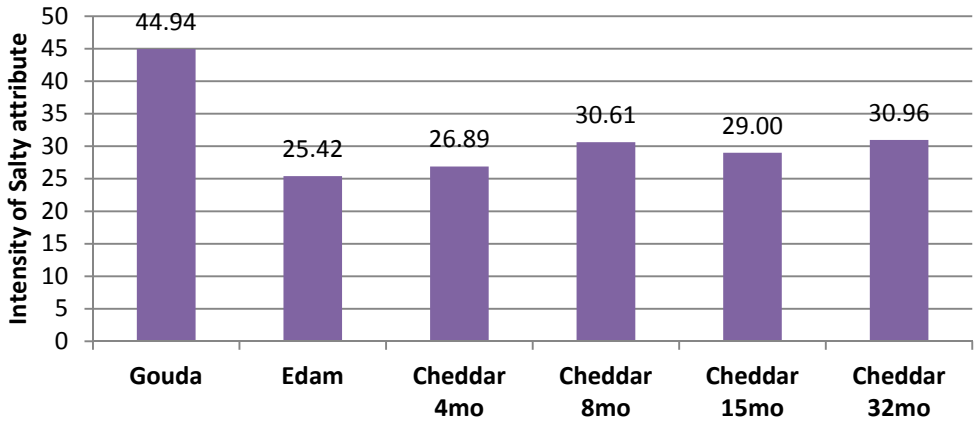

Figure 24 Intensity levels of salty taste as the cheese samples aged.

3.4.4 Bitter taste

The overall level of bitterness in the cheese samples was extremely low as scores ranged from 0.00 to 8.92 (Table 8). No bitter taste was identified in Edam and at extremely low levels in Gouda and Cheddar at 4 months. These three samples were not significantly different from one another ($p>0.05$). Cheddar at 32 months received the highest score for bitter, followed by Cheddar at eight months and finally Cheddar at 15 months. Interestingly, the levels of bitter taste were significantly different for these three cheeses. There was no progressive increase in bitter taste as the samples aged (Figure 25). This does not correspond with literature which indicates bitter taste in Cheddar cheese increases with ageing (Muir *et al.*, 1992; Muir *et al.*, 1996; Drake *et al.,* 2008). Results for Cheddar at 15 months once again indicated a significantly lower level of bitter taste than Cheddar at eight and 32 months. Bitterness is considered a defect in Cheddar cheese and associated with the production of bitter peptides which contain predominantly hydrophobic amino acid residues (Singh *et al.*, 2003).

Investigation of the significant correlation values ($p<0.05$) revealed positive correlations with Cheddar aroma ($r = 0.941$), brothy aroma ($r = 0.912$), whey aroma ($r = 0.988$), visible white crystals

(r = 0.969), moisture seepage (r = 0.959), caramel-sweet (r = 0.965), brothy flavour (r = 0.941), lingering cheese flavour (r = 0.935), Cheddar flavour (r = 0.9905) and prickle (r = 0.945). These flavours are generally associated with aged and mature cheese flavours (Drake *et al.*, 2001; Drake *et al.*, 2002; Young *et al.*, 2004), which suggests that bitter taste is associated with the flavour development of an older cheese.

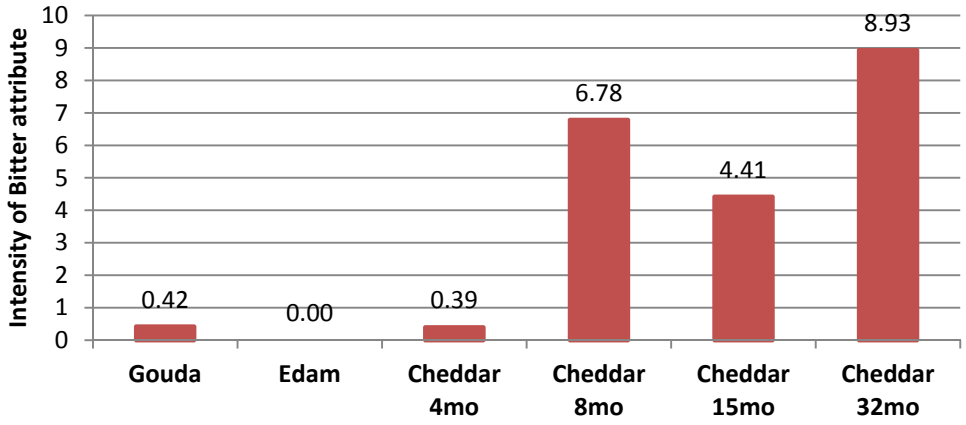

Figure 25 Intensity levels of bitter taste as the cheese samples aged.

3.4.5 Creamy flavour

Mean intensity scores for the attribute creamy flavour ranged from 29.86 to 53.54, indicating that a high level of creamy flavour was perceived in the cheeses (Table 8). Gouda and Edam at 1 and 2 months of age, respectively, received the highest scores for creamy flavour. The lowest score was identified in Cheddar at 8 months. Perception of creamy flavour decreased with age, however, the 15 month old was perceived to be creamier than both Cheddars at 8 and 32 months (Figure 26).

Investigation of the correlation values ($p<0.05$) revealed positive relationships with glossy appearance (r = 0.943), springiness (r = 0.966) and cohesiveness (r = 0.905). Negative correlations were identified with the Cheddar aroma (r = -0.987), brothy aroma (r = -0.988), moisture seepage (r = -0.935), caramel sweet (r = -0.942), sour (r = -0.922), brothy flavour (r = -0.980), lingering cheese flavour (r = -0.985), Cheddar flavour (r = 0.993), prickle (r = -0.988), firmness (r = -0.971), hardness (r = -0.907), crumbliness (r = -0.992), graininess (r = -0.925), and teeth-coating (r = -0.917). These results suggest that creamy flavour is associated with the flavour development of a young cheese. It has been frequently reported that the perception of creamy flavour in Cheddar cheese is indicative of a young cheese and associated with mild and undeveloped flavours (Drake *et al.*, 2001; Carunchia Whetstine *et al*., 2007, and Drake *et al.*, 2008).

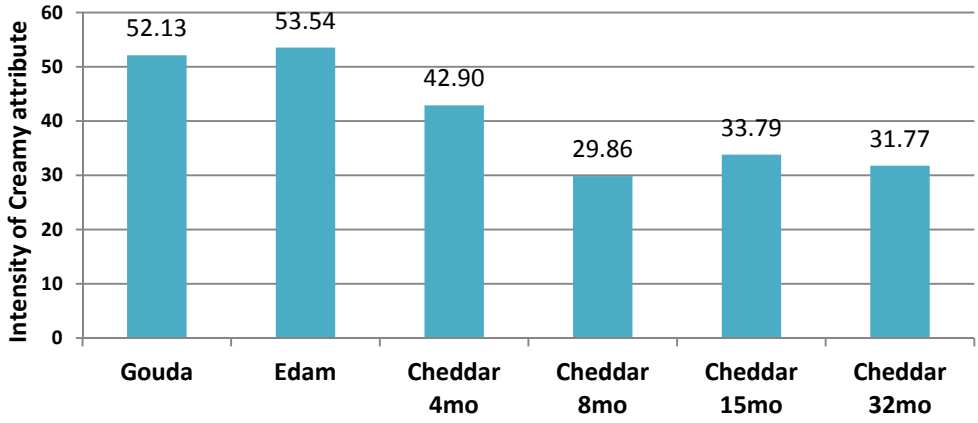

Figure 26 Intensity levels of creamy flavour as the cheese samples aged.

3.4.6 Caramel-sweet taste

Mean intensity scores for the attribute caramel-sweet ranged between 0.30 and 6.52, indicating that although perceivable in some of the samples, it was not present in all samples (Table 8). The oldest cheese, at 32 months, received the highest score for caramel-sweet, while the Edam at two months received the lowest score. Gouda and the Cheddar samples aged to 4, 8 and 15 months were not significantly different from one another in the levels of caramel sweet intensity. A progressive increase was seen from Edam through to the Cheddar at 32 months, however, the level dropped in the 15 month old Cheddar cheese (Figure 27).

Positive correlations were identified with Cheddar (r = 0.974) and brothy aroma (r = 0.972) attributes; appearance attributes of visible white crystal (r = 0.923) and moisture seepage (r= 0.920); flavour attributes of brothy (r = 0.942), lingering cheese (r = 0.979), Cheddar (r = 0.961) and prickle (r = 0.963); and texture attributes of firmness (r = 0.939), crumbliness (r = 0.920), graininess (r = 0.920) and teeth-coating (r = 0.963). A negative correlation was identified with creamy flavour (r = 0.942). These results suggest that the attribute caramel-sweet describes an aged cheese. Lawler *et al.* (2002) found positive correlations between caramel flavour and certain free amino acids (isoleucine, serine, histidine, threonine, proline, methionine, leucine, valine, phenylalanine, lysine and glutamic acid).

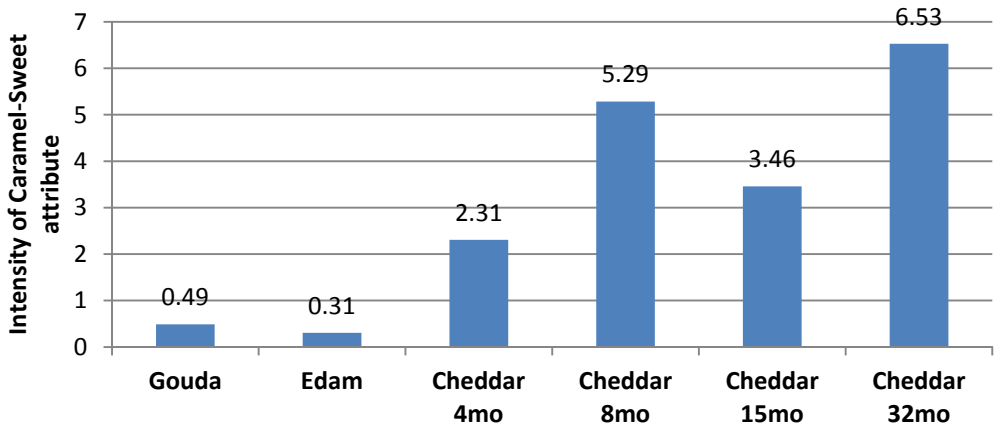

Figure 27 Intensity levels of caramel-sweet as the cheese samples aged.

3.4.7 Brothy flavour

Mean intensity scores for brothy flavour ranged from 0.00 to 26.70 indicating that this attribute, although perceived in some of the cheeses, was at low levels (Table 8). The attributed differentiated the cheese samples by age (Figure 28). Brothy flavour was not perceived in the Edam cheese and at low levels in the Gouda. Cheddar at 8 months received the highest score for brothy flavour; however, this was not significantly different from the 32 month old Cheddar cheese, which received the second highest score for brothy flavour. The level of brothy flavour dropped in the Cheddar at 15 months. This is unexpected as brothy flavour is generally associated with flavours identified in aged cheeses (Drake *et al.,* 2001).

Positive correlations were identified with Cheddar (r = 0.983) and brothy (r = 0.963) aroma, appearance attributes of visible white crystals (r = 0.919) and moisture seepage (r = 0.981); flavour attributes of caramel-sweet (r = 0.942), bitter (r = 0.941), lingering cheese (r = 0.976), Cheddar (r = 0.971) and prickle (r = 0.996), and texture attributes of firmness (r = 0.925), crumbliness (r = 0.978), graininess (r = 0.976) and teeth-coating (r = 0.963). Negative correlations were identified with creamy flavour (r = -0.980) and springiness (r = -0.908). These results would indicate that brothy flavour is associated with aged flavour development in cheese. The origin of the compounds found to be responsible for the beefy/broth-like notes can be explained by the catabolic activity of the starter bacteria and /or the Maillard reaction. Compounds contributing to the specific broth-like notes in Cheddar cheese include methional, furaneol and 2-methyl-3-furanthiol (MFT) (Cadwallader *et al*., 2006).

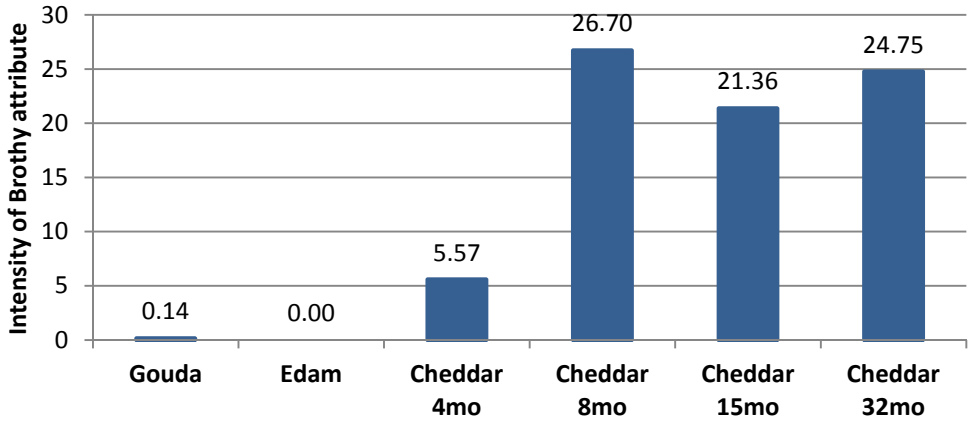

Figure 28 Intensity levels of brothy flavour as the cheese samples aged.

3.4.8 Lingering cheese flavour

Mean intensity scores for lingering cheese flavour ranged from 16.63 to 60.48, indicating that the attribute was perceivable in all samples, however, at low levels in the Gouda and Edam (Table 8). This attribute differentiated the cheeses by age and progressively increased as the cheeses aged (Figure 29). Cheddar at 15 months, however, received lower intensity scores and was significantly different from both Cheddars at 8 and 15 months.

Positive correlations were identified with Cheddar and brothy (r = 0.998) aroma attributes; visible white crystals (r = 0.915) and moisture seepage (r = 0.946); bitter taste (r = 0.935), caramel-sweet (r = 0.979), brothy (r = 0.976), Cheddar (r = 0.995) and prickle (r = 0.989) flavours and texture attributes of crumbliness (r = 0.978), graininess (r = 0.940), firmness (r = 0.978) and teeth-coating (r = 0.949). Negative correlations were identified with glossy appearance (r = -0.940), creamy flavour (r = -0.985) and springiness (r = -0.954), attributes that are usually associated with young cheese.

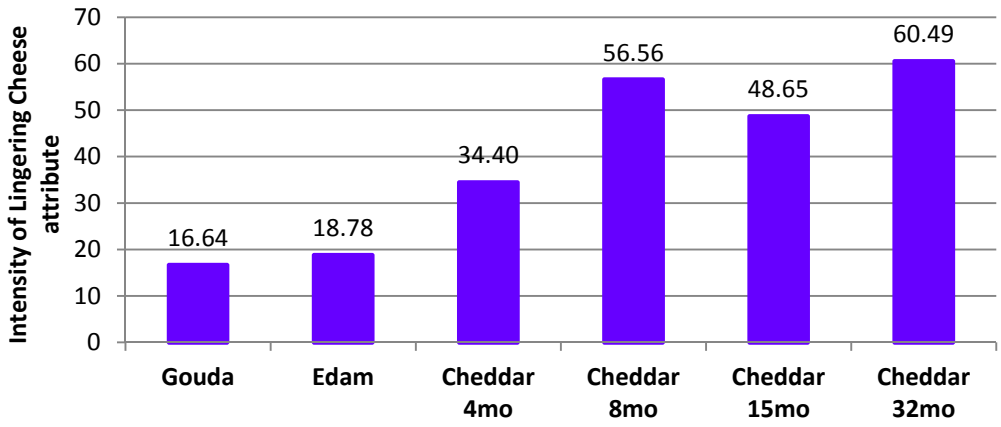

Figure 29 Intensity levels lingering cheese flavour as the cheese samples aged.

3.4.9 Cheddar flavour

Mean intensity scores for Cheddar flavour ranged between 0.00 and 63.41 indicating that this attribute was not perceived in the younger cheeses Gouda and Edam (Table 8). Cheddar flavour differentiated the Cheddar samples by age. The Cheddar cheeses aged to 8 and 32 months received the highest scores for this attribute, however, the Cheddar sample aged to 15 months showed a lower level of this attribute than the Cheddar samples aged to 8 and 32 months (Figure 30).

Positive correlations were identified with Cheddar (r = 0.995) and brothy (r = 0.998) aroma; moisture seepage (r = 0.936); flavour attributes of caramel sweet (r 0.961), sour (r = 0.911), bitter (r = 0.905), brothy (r = 0.971), lingering cheese (r = 0.995) and prickle (r = 0.983) and texture attributes of firmness (r = 0.988), hardness (r = 0.919), crumbliness (r = 0.989), graininess (r = 0.926) and teethcoating (r = 0.919). The latter attributes all associate with mature Cheddar.

Negative attributes were identified with glossy appearance (r = -0.956), creamy flavour (r = -0.993) and springiness (r = -0.974), again attributes that associate with a younger cheese. Muir *et al.* (1992) reported that the perception of maturity was dominated by the intensity of Cheddar cheese flavour and an increase in Cheddar flavour intensity was one of the main changes associated with ripening. A loose association between Cheddar intensity and fat content of Cheddar cheese was found by Banks, Hunter and Muir (1994). No relationship between fat content and Cheddar flavour intensity was identified in this experiment.

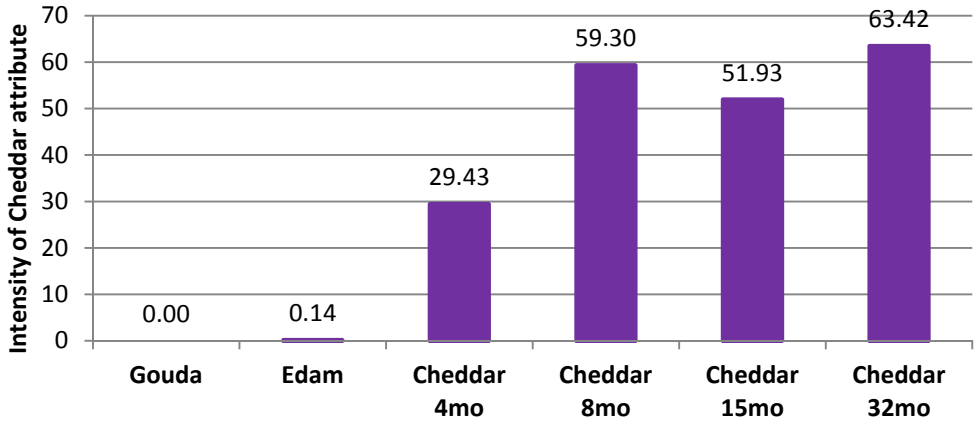

Figure 30 Intensity levels of Cheddar flavour as the cheese samples aged.

3.4.10 Prickle flavour

Mean intensity scores for the attribute prickle flavour ranged from 0.00 to 27.12 (Table 8). The prickle attribute was not perceived in either the Gouda or the Edam cheese, while Cheddar at 8 and 32 months respectively, received the highest score. An increase in this attribute was observed in the older cheeses, however, Cheddar at 15 months received a lower score than Cheddar at 8 months (Figure 31).

Positive correlations were observed for Cheddar (r = 0.991) and brothy (r = 0.980) aroma attributes, visible white crystals (r = 0.914) and moisture seepage (r = 0.991), flavour attributes of caramel-sweet (r = 0.963), bitter (r = 0.945), brothy (r = 0.996), lingering cheese (r = 0.989) and Cheddar (r = 0.983) flavour attributes and texture attributes of firmness(r = 0.945), crumbliness (r = 0.979), graininess (r = 0.963) and teeth-coating (r = 0.967). Negative correlations were identified with glossy appearance (r = -0.908), creamy flavour(r = -0.988) and springiness (r = -0.926).

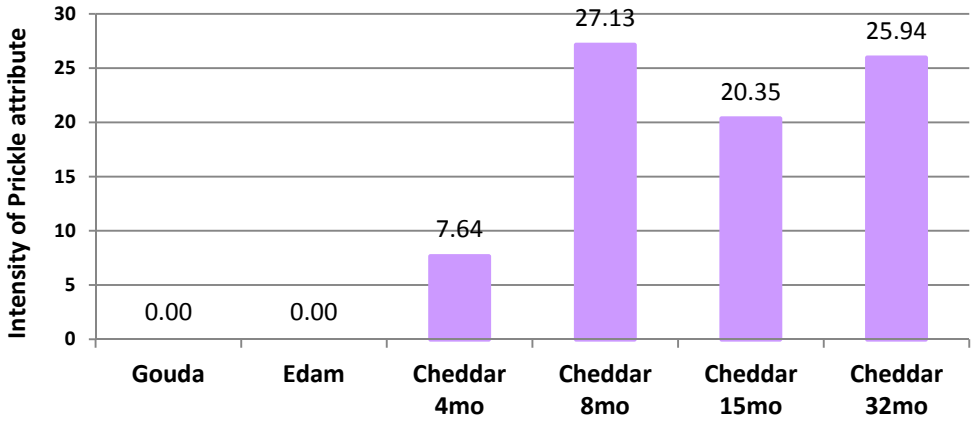

Figure 31 Intensity levels of the prickle flavour attribute as the cheese samples aged.

3.5 Texture attributes

ANOVA results determined significant differences between the treatment means for all of the texture attributes at a significance level of 5%. The mean sensory attribute scores for texture and their least significant difference for the six samples of cheese are listed in Table 9.

The eight texture attributes differentiated and characterised the six cheese samples. The attributes creamy, springy and rubbery described the younger cheeses at 1 and 2 months of age (Figure 32 and 33). The older cheeses at 8, 15 and 32 months were predominantly characterised by the attributes creamy, firm, hard, crumbly, grainy and teeth-coating (Figure 35, 36 and 37). Consistent with those results published by Muir *et al.* (1995), the 4 month old Cheddar cheese was characterised by both the young and aged texture attributes (Figure 34). As the cheeses matured, progressive increases in firmness, hardness, crumbliness, graininess and teeth-coating were observed, while creaminess remained constant in the older cheeses. Springiness declined and rubberyness was not identified in the Cheddar samples.

Table 9 Mean intensities for texture attributes of the six cheese samples.

	Creaminess	Springiness	Rubbery	Firmness	Hardness	Crumbliness	Graininess	Teeth-coating
Treatment	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean	[2] Mean
Gouda	58.01^{a}	62.98^{a}	3.83^{b}	45.74^{d}	11.31^{c}	0.42^{c}	0.56^{c}	0.69^{c}
Edam	42.31^{c}	57.77^{b}	14.30^{a}	47.38^{d}	16.45^{b}	0.28^{c}	0.56^{c}	1.38^{c}
Cheddar 4mo	47.04^{b}	17.15^{c}	0.66^{c}	65.31^{c}	28.54^{a}	8.61^{b}	0.54^{c}	1.69^{c}
Cheddar 8mo	46.05^{cb}	0.88^{d}	0.00^{c}	73.55^{ba}	30.91^{a}	19.77^{a}	19.00^{b}	11.12^{a}
Cheddar 15mo	46.86^{b}	1.76^{d}	0.00^{c}	72.12^{b}	29.97^{a}	19.64^{a}	17.85^{b}	6.57^{b}
Cheddar 32mo	47.19^{b}	1.08^{d}	0.00^{c}	77.90^{a}	29.42^{a}	19.45^{a}	22.25^{a}	11.65^{a}
[1] LSD	**4.36**	**2.10**	**2.67**	**4.45**	**2.72**	**2.12**	**2.67**	**2.52**

[1] Least Significant Difference (p=0.05)

[2] Values with the same superscript are not significantly different

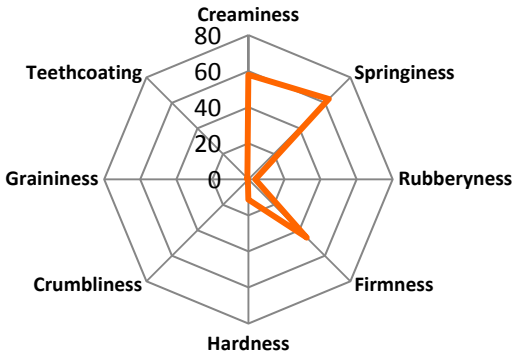

Figure 32 Texture characterisation of Gouda cheese sample at 1 month in age.

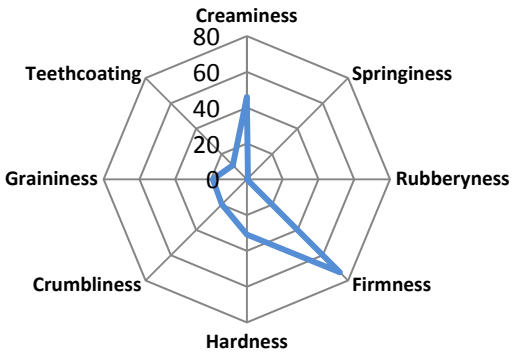

Figure 35 Texture characterisation of Cheddar cheese sample at 8 months in age.

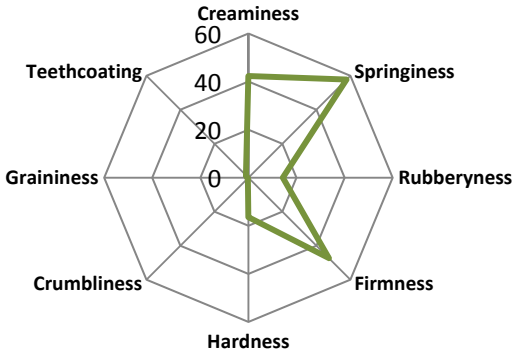

Figure 33 Texture characterisation of Edam cheese sample at 2 months in age.

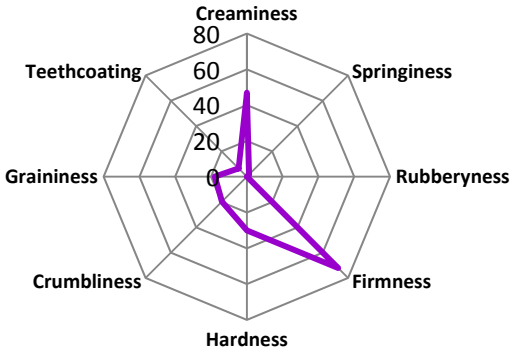

Figure 36 Texture characterisation of Cheddar cheese sample at 15 months in age.

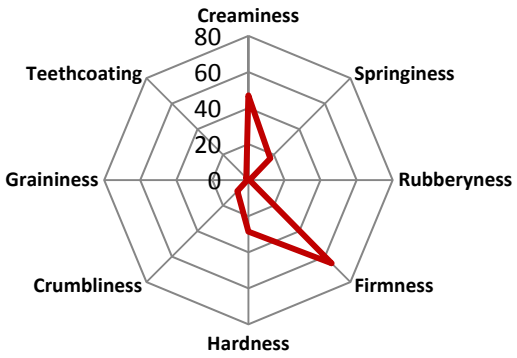

Figure 34 Texture characterisation of Cheddar cheese sample at 4 months maturity.

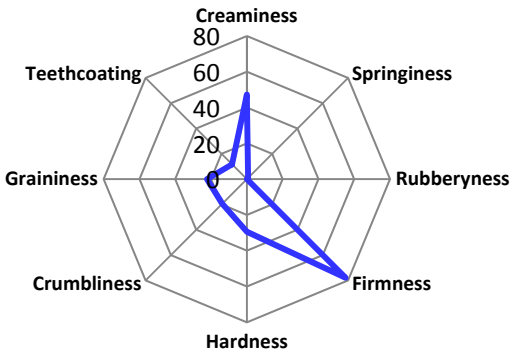

Figure 37 Texture characterisation of Cheddar cheese sample at 32 months maturation.

3.5.1 Creaminess

Creaminess describes the extent to which the cheese has a velvety mouthfeel and was measured from not very creamy to very creamy. Scores for creaminess ranged between 42.31 and 58.01 (Table 9), indicating that the level of creaminess fell mid-way on the scale and was identified in all six cheeses. The attribute did not differentiate the cheese samples by age and neither did the level of creaminess increase significantly during maturation of the Cheddar cheeses (Figure 38). This is in contrast to the results published by Hort *et al*. (1997) and Hort and Le Grys (2001) who found that the creamy character of Cheddar cheese increased during maturation. These authors suggest that the disintegration of the casein network results in a smoother, more homogenous structure and consequently an increase in the creaminess character. A creamy texture is often associated with fat (Fenelon, Guinee, Delahunty, Murray and Crowe, 2000) and/or moisture content (Drake and Swanson, 1995). No correlations in this research, however, were identified between creaminess and either fat content or moisture content.

Gouda received the highest score for creamy texture. Although this cheese did not have the highest fat content, it did have the highest moisture content at 41.88%, which may have contributed to the perception of creaminess. Drake and Swanson (1995) suggest that increasing the moisture content of a cheese can contribute to the lubricity or creamy mouthfeel provided by fat. This manipulation of the fat/moisture content is evident in results obtained for the reduced fat Edam cheese. The reduction in fat (23.63%) was compensated for by the higher level of moisture, (39.98%), which contributed to a level of creaminess in the cheese, albeit at a significantly different level when compared with the other cheeses. The Cheddar samples at 4, 15 and 32 months received similar scores for the attribute of creaminess. The fat content for these samples ranged between 32.77% and 33.90%. Cheddar at 8 months had the highest fat content of the four Cheddar samples at 34.77%, however, the level of creaminess in this cheese was only slightly less than that of the other Cheddar samples. These results suggest that fat content did not necessarily contribute to the perception of creamy texture.

Examination of the correlation values ($p<0.05$) indicated a significant positive relationship between creaminess and salty ($r = 0.965$) and sour cream aroma ($r = 0.891$), suggesting that a high level of creamy texture may be associated with higher levels of salty taste and sour cream aroma.

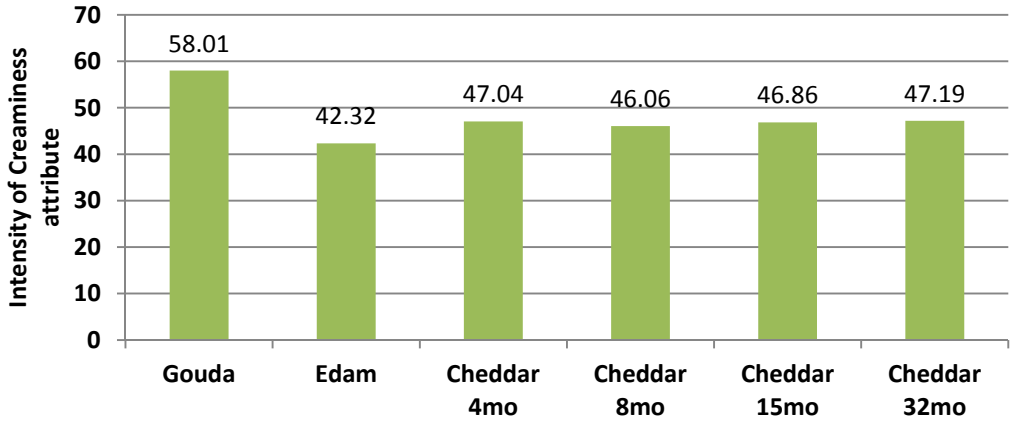

Figure 38 Intensity levels of creaminess as the cheese samples aged.

3.5.2 Springiness

The attribute describes the extent to which the cheese springs back when compressed and ranged in this study from not springy to very springy. Scores for springiness ranged between 0.88 and 62.98 (Table 9), indicating a large variation in the degree of springiness between samples (Figure 39). Springiness differentiated the younger cheeses from the older ones as this attribute was perceived in the two young cheeses and at extremely low levels in the more mature cheeses. Gouda received the highest score for springiness at 62.98, followed by Edam at 57.77. Gouda and Edam recorded the highest moisture content levels of the six samples at 41.88% and 39.98% respectively. This may have contributed to the perception of springiness, which is further supported by springiness correlating positively with moisture (r =0.921). This result corresponds with those published by Carunchia Whetstine *et al.* (2007), who found that higher moisture content was associated with a springier and cohesive texture, as well as an increase in mouth coating. They suggest that the higher moisture content is related to a less rigid cheese matrix. The lowest perceived level of springiness was detected in the eight month old Cheddar, which interestingly, also recorded the lowest moisture content at 35.70%. Jack and Paterson (1992) suggested that an increase in moisture content reduced the resistance to and increased the recovery from deformation (Jack, and Paterson, 1992).

Further examination of the correlation values indicated that the attribute springiness was positively associated with young cheese attributes of glossy appearance (r = 0.991), creamy flavour (r = 0.966) and moisture content (r = 0.92). Hort *et al*. (1997) identified a significant correlation between pH and springiness, suggesting a strong relationship between the extent of proteolysis and the attribute springiness, however, no such relationship was identified in this research.

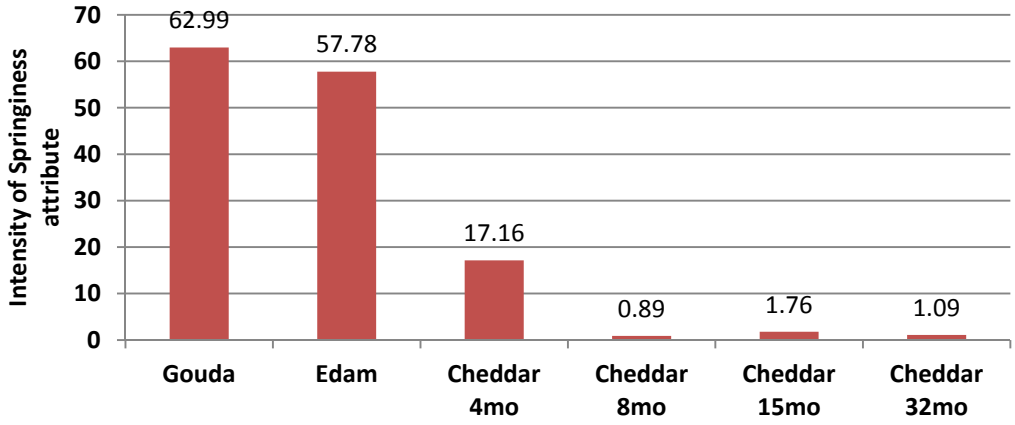

Figure 39 Intensity levels of springiness as the cheese samples aged.

3.5.3 Rubbery texture

The attribute describes the extent to which the sample pushes back against the molars during chewing and ranged in this study from not rubbery to very rubbery. Scores for rubbery texture ranged from 0 to 14.30 (Table 9), indicating that the attribute was perceived over a narrow range and in only some of the cheeses (Figure 40). Rubbery texture was clearly associated with only the two younger cheeses, Gouda and Edam. The four older cheeses were not considered rubbery in texture. A significant negative correlation (r =-0.983) was identified between rubbery texture and fat content, which is apparent in Edam receiving the highest score for rubbery texture. Significant positive relationships were found between rubbery texture and buttery (r = 0.972) and creamy aroma (r = 0.943). This indicates that a rubbery texture can be associated with the flavour and texture development of a young and / or reduced fat cheese.

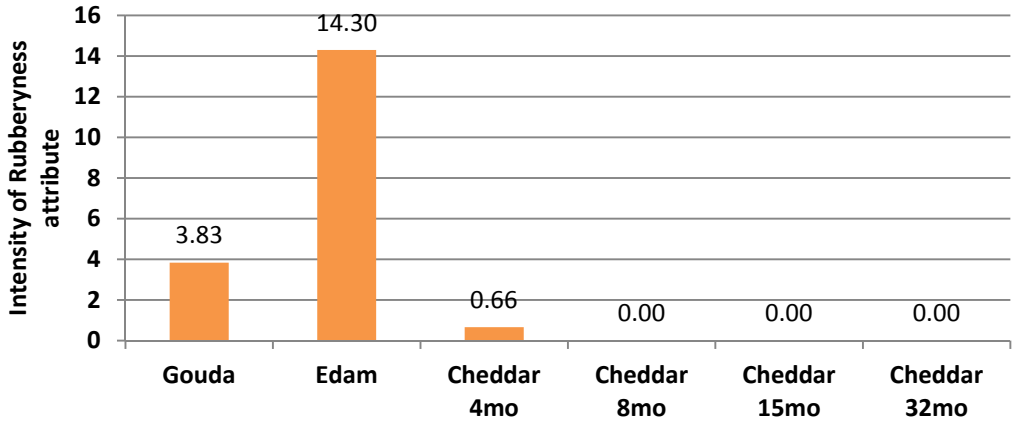

Figure 40 Intensity levels of rubbery texture as the cheese samples aged.

3.5.4 Firmness

Firmness measures the force required to compress the cheese with the fingers and ranged in this study from soft to firm. Scores ranged between 47.38 and 77.90 (Table 9), indicating that the attribute was perceivable in all the cheeses and over a wide range (Figure 41). The attribute

differentiated the cheeses by age as the highest levels of firmness were identified in the older cheeses. A progressive increase in firmness was also observed as the cheeses matured. Gouda scored the lowest for this attribute, while the 32 month matured Cheddar received the highest score. This follows a similar pattern with those results of Hort *et al.* (1997) and Hort and Le Grys (2001). In their research, however, the attribute firmness decreased after 64 weeks of maturation. Interestingly, a negative correlation was identified in this study between firmness and moisture content (r = -0.885) suggesting that cheeses with a lower moisture content may be perceived as firmer than those with a higher moisture content. Green and Manning (1982) confirmed that the firmness of cheese depends largely on moisture content which acts mainly by influencing the rate of proteolysis. Results published by Carunchia-Whetstine (2007) identified a lower moisture content and higher level of protein hydrolysis in the inner areas of 291 kg blocks of Cheddar cheese. This corresponded with higher sensory "hand" firmness. It was concluded that higher hand firmness was consistent with the lower moisture content (Carunchia Whetstine *et al.*, 2007). Further examination of the correlation values illustrated significant positive relationships with attributes associated with flavours predominately found in aged cheeses (Drake *et al.*, 2001; Young, *et al*., 2004) and negative correlations with those attributes associated with young and undeveloped cheese flavours. This suggests that higher levels of firmness in a cheese may be associated with texture of older cheeses.

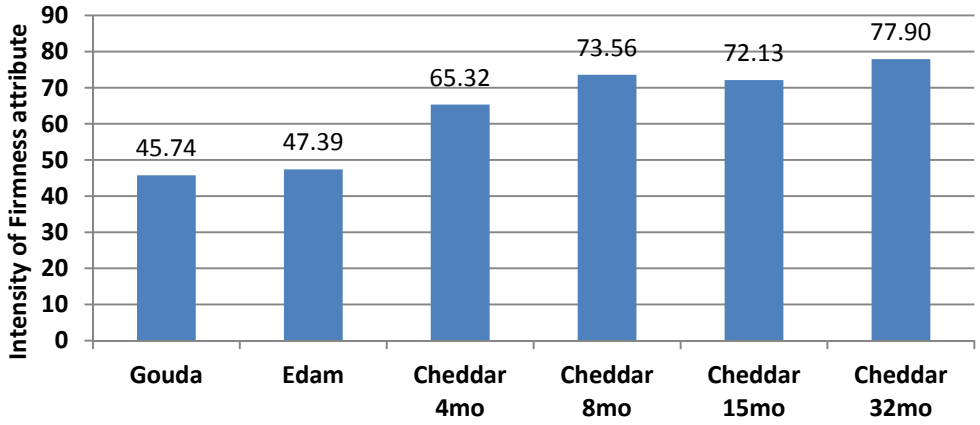

Figure 41 Intensity levels of firmness as the cheese samples aged.

3.5.5 Hardness

Scores for hardness ranged between 11.31 and 30.91, indicating that the attribute was identified in all the cheese samples, however, towards the lower end of the scale (Table 9; Figure 42). Hardness measures the force required to penetrate the cheese with a knife or teeth and the line scale in this study ranged from not very hard to hard. The attribute differentiated the cheeses by age and increased as the cheeses matured. Gouda at 1 month received the lowest score for hardness, followed by Edam at 2 months maturity. Eight month matured Cheddar received the

highest score for hardness, which is interesting since it was not the oldest cheese. This cheese did, however, have the lowest moisture content of the six cheeses. Nevertheless, the scores for hardness in all four Cheddar samples were not significantly different from one another ($p>0.05$). Positive correlations were identified with brothy aroma ($r = 0.914$), Cheddar flavour ($r = 0.919$) and crumbliness ($r = 0.905$), suggesting that this attribute can be associated with the flavour development of older cheeses (Drake *et al*., 2001; Young *et al*., 2004). Negative correlations were identified with glossy appearance ($r = -0.988$), creamy flavour ($r = -0.907$), springiness ($r = -0.979$), and moisture content ($r = -0.955$), the latter attributes being associated with younger cheese. Lawrence, Creamer and Gilles (1987) suggest that during proteolysis, as each peptide bond is cleaved, two new ionic groups are generated. Each of these will compete for available water in the system. The water previously available for solvation of the protein chains will become tied up with new ionic groups. Relatively low moisture cheese, such as Cheddar, tends to become increasingly harder with age and more resistant to slight deformation.

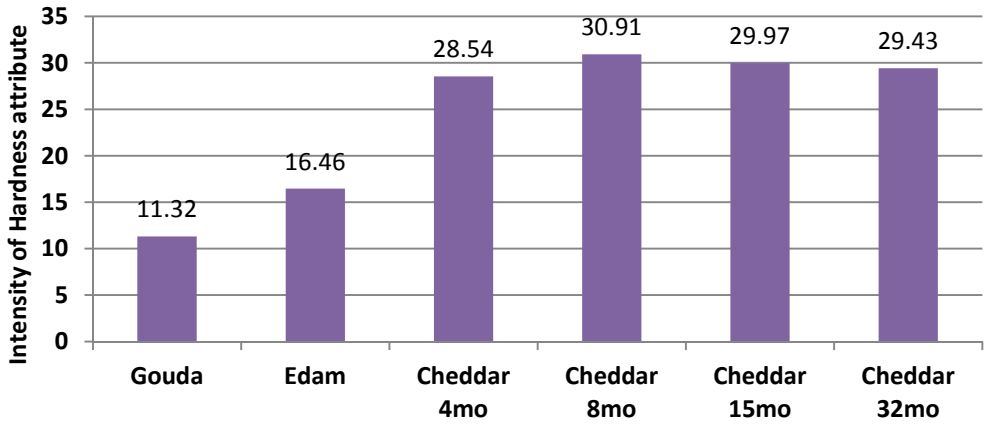

Figure 42 Intensity levels of hardness as the cheese samples aged.

3.5.6 Crumbliness

Scores for crumbliness ranged between 0.28 and 19.77 (Table 9), indicating that although the attribute was perceived in the cheeses, it was at lower levels (Figure 43). The attribute describes the extent to which a sample breaks when chewed or compressed, and ranged in this study from not crumbly to very crumbly. Crumbliness differentiated the cheeses by age. A progressive increase in crumbliness occurred as the cheeses matured. Cheddar samples at 8, 15 and 32 months maturity were identified as the most crumbly although there was little perceived variation between the three cheeses. The Gouda and Edam samples were not characterised as being crumbly. Cheddar cheese at 4 months was significantly different from the rest of the cheeses ($p>0.05$). This cheese was not as crumbly as the older Cheddar cheeses but still showed more crumbliness than Gouda and Edam. This is consistent with findings reported by Banks *et al*. (1994) and Hort and Le Grys (2001). O'Callaghan and Guinee (2004) suggest that crumbliness,

shortness and fracturability may result from an occurrence of structural discontinuities and lack of tensile strength within the cheese.

Examination of the correlation values ($p<0.05$) indicated that crumbliness was positively associated with flavours predominantly found in older cheeses (Drake *et al.*, 2001; Young *et al.*, 2004) Cheddar aroma (r = 0.984), brothy aroma (r = 0.979), moisture seepage (r = 0.950), caramel-sweet (r = 0.920), brothy flavour (r = 0.978), lingering cheese flavour (r = 0.978), Cheddar flavour (r = 0.989), prickle flavour (r = 0.979), firmness (r = 0.969), hardness (r = 0.905), graininess (r = 0.939) and teeth-coating (r = 0.900). Negative correlations were identified with glossy appearance (r = -0.951) and springiness (r = -0.967). Crumbliness in these cheese samples can therefore be associated with the texture development of older cheeses. In this study, cheeses that were characterised by a glossy appearance and springiness were not crumbly.

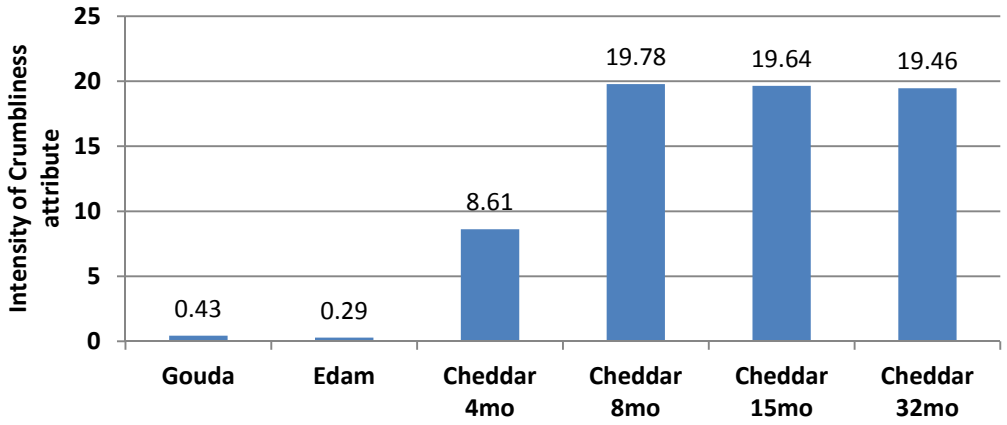

Figure 43 Intensity levels of crumbliness as the cheese samples aged.

3.5.7 Graininess

Scores for graininess ranged between 0.54 and 22.50 (Table 9), suggesting that the attribute was present in the cheese samples, however, at low levels (Figure 44). Graininess measures the extent to which the cheese is "bitty" towards the end of chewing and ranged in this study from not grainy to very grainy. This attribute differentiated the cheeses by age, with higher levels identified in the older cheeses. The Gouda, Edam and 4 month Cheddar were not perceived to be grainy whereas Cheddar cheeses at 8, 15 and 32 months were characterised by some level of graininess. Graininess increased with the age of the cheese. The Cheddar aged to 32 months received the highest score and was significantly ($p<0.05$) more grainy than the samples aged to 8 and 15 months.

Positive correlations were identified with flavours predominantly found in older cheeses, Cheddar aroma (r = 0.955), brothy aroma (r = 0.918), visible white crystals (r = 0.973), moisture seepage (r = 0.999), caramel-sweet (r = 0.920), bitter taste (r = 0.966), brothy flavour (r = 0.976), lingering cheese flavour (r = 0.940), Cheddar flavour (r = 0.926), prickle (r = 0.963), crumbliness (r = 0.939), and teeth-coating (r = 0.961). Negative correlations were identified with creamy flavour (r = -

0.925), glossy appearance (r = -0.819) and springiness (r = -0.832). These results suggest that higher levels of graininess may be associated with the texture profile of older cheeses. As levels of graininess increase, creamy flavour, glossy appearance and springiness tend to decrease.

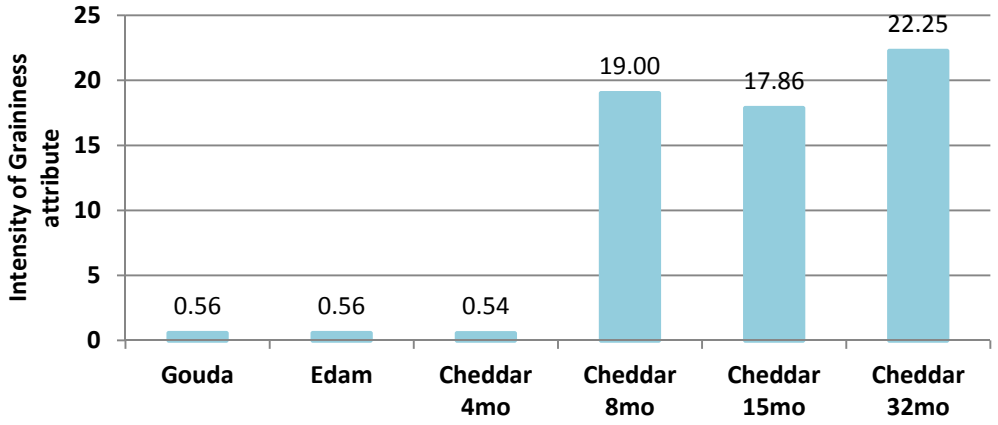

Figure 44 Intensity levels of graininess as the cheese samples aged.

3.5.8 Teeth-coating

Teeth-coating measures the degree to which the sample sticks to the molars during chewing and ranged in this study from not sticky to very sticky. Scores for teeth-coating ranged between 0.69 and 11.65 (Table 9), indicating that the attribute was identified in the samples, however, at very low levels (Figure 45). The attribute differentiated the cheeses by age, as higher levels were identified in the older cheeses. Extremely low levels of teeth-coating were found in the three younger cheeses at one, 2 and 4 months of age. Cheddar at 15 months, however, displayed an unusual result. The level of teeth-coating in this cheese was significantly ($p<0.05$) lower than that of the Cheddar at 8 months of age. The Cheddar samples at 8 and 32 months were perceived to have the same level of teeth-coating.

Positive correlations, as expected, were identified with flavours found in older cheeses (Drake *et* al, 2001; Young *et al.*, 2004). Cheddar aroma (r = 0.948); brothy aroma (r = 0.923), whey aroma (r = 0.946) and visible white crystals (r = 0.931), lingering cheese flavour (r = 0.949), Cheddar flavour (r = 0.919), prickle flavour (r = 0.967), crumbliness (r = 0.900) and graininess (r = 0.961). These attributes generally characterise the texture of an older cheese, which suggests that higher levels of teeth-coating may describe the texture attributes of older cheeses. Negative correlations were identified with creamy flavour (r = -0.917) and springiness (r = -0.815).

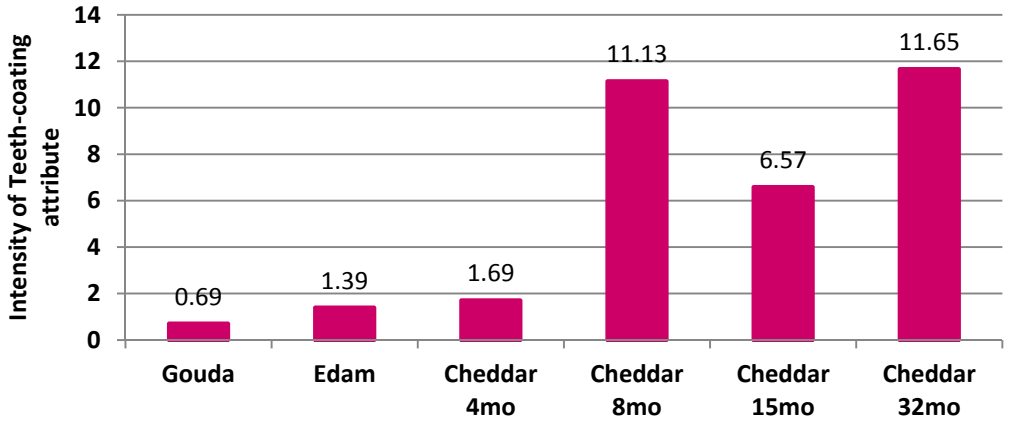

Figure 45 Intensity levels of teeth-coating as the cheese samples aged.

4. CONCLUSIONS

It is evident from the results reported that DSA of Cheddar cheese is vital in characterising and describing those sensory qualities that differentiate one cheese from another.

Six cheese samples, including a Gouda, an Edam and four Cheddar cheeses, all varying in age and composition were successfully profiled by using DSA. A panel of six judges was trained using three established lexicons, detailing the aroma, flavour and texture attributes of Cheddar cheese. The panel determined a final set of sensory attributes, consisting of three appearance, seven aroma, ten flavour and eight textural attributes, each with its own descriptor, description and reference standard.

The attributes successfully differentiated the cheese samples by age. Younger cheeses were described as glossy, with a buttery and creamy aroma, a creamy flavour, salty and slightly sour taste combined with a lingering cheese flavour. Texture was characterised by creaminess, springiness and rubberyness. As the cheeses aged, characterisation encompassed visible white crystals and moisture seepage; brothy and Cheddar aromas, sour taste, salty taste, brothy, Cheddar and prickle flavours. Texture was characterised by firmness, hardness, crumbliness, graininess and teeth-coating.

Moisture content and pH played a role in the flavour development of the 8 and 15 month matured Cheddar cheese samples. The Cheddar aged to 8 months developed higher intensities of aged flavours, similar to that of the cheese aged to 32 months. This cheese had the lowest moisture content of the four Cheddar samples. Cheddar at 8 and 32 months were predominantly characterised by the same intensities of whey and brothy aromas, caramel-sweet, brothy, lingering cheese, Cheddar and prickle flavours. In contrast, the Cheddar sample at 15 months displayed slower flavour development, with fewer aged flavours and higher intensities of young flavours evident. It is believed that the low pH of this cheese influenced the ripening enzymes and their subsequent contribution to proteolysis and flavour development.

As a scientific method, DSA can be successfully applied in quality control, new product development and academic research to provide an informative sensory description of Cheddar cheese. Furthermore, the information derived can be used to determine relationships between the data and consumer preference measurements.

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CHAPTER 4

INSTRUMENTAL ANALYSIS OF CHEESE COLOUR

1. INTRODUCTION

Colour strongly influences consumer perception of quality (Frances, 1995; Lawless and Heymann, 2010). Furthermore, it is the first impression a consumer has of a given food product and should fall within an expected colour range for food acceptance to occur (Francis, 1995).

Lawless and Heymann (2010) describe colour as the perception that results from the detection of light after it has interacted with an object and is affected by the physical and chemical composition of the object, the spectral composition of the light source illuminating the object and the spectral sensitivity of the viewer's eye. Francis (1995) further defines colour as the impact of the wavelengths of light in the visual spectrum of 390 to 760 nm on the human retina.

Instrumental methods of colour evaluation are often considered more reliable and less expensive than descriptive sensory analysis (Jack and Paterson, 1992). In fact, Lawless and Heymann (2010) recommend that when conducting visual colour measurements as part of a sensory analysis, details such as background colour in the viewing area, light source in Kelvin and its intensity at the product surface, panellists viewing angle and the angle of light incidence on the sample, distance from the light source and the product and finally whether the sample is lit with reflected or transmitted light should be controlled, standardised and reported on during the analysis. Instruments on the other hand are able to produce empirical measurements of colour fairly easily. To their disadvantage, however, they are incapable of predicting consumer acceptability or assessing complex sensory properties valued by humans (Jack and Paterson, 1992).

During the manufacture of cheese, annatto, a natural colour extracted from the seeds of the *Bixa orellana,* is added to the milk to enhance cheese colour (Fox and McSweeney, 2004). The colour is composed of tints of yellow and red units which, in cheese, attach to the casein as a protein dye (Robinson and Wilbey, 1998). Cheese colour may further be influenced by the initial cheese milk composition, manufacturing procedures and maturation conditions (Lucey, Johnson, and Horne, 2003). Although the depth of colour is specific to each variety of cheese, it has no effect on the cheese flavour and the formula usually stipulates the type of colour and quantity (Robinson and Wilbey, 1998).

The CIE L*a*b* Colour System provides a standard, approximately uniform colour scale. In a uniform colour scale, the differences between points plotted in the colour space correspond to

visual differences between the colours plotted. The L - axis reflects the lightness of a sample, from black (L = 0) to white (L = 100) and runs from top to bottom. The larger the values of L*, the lighter the colour. The a-axis defines the shades from red (positive values) to green (negative values). A high value for a* reflects a more reddish hue, while a negative value reflects a more greenish hue. The b-axis defines the shades from yellow (positive values) to blue (negative values). Any colour that can be visually perceived can be plotted on the L*, a*, b* rectangular space (CIE L*a*b* Colour scale, 2008).

The primary objective of this study was to determine instrumental colour attributes of the six cheese samples. A secondary objective was to establish whether colour distinguished the samples by age and finally to confirm whether colour changes occurred as the cheese samples matured.

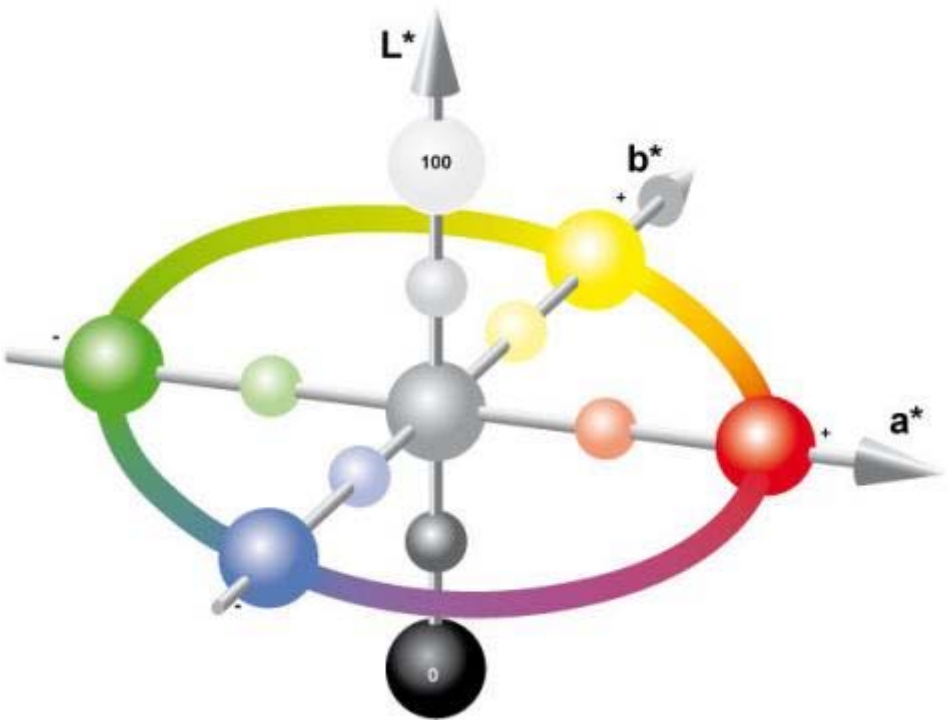

Figure 1 CIE L*a*b* colour space (CIE L*a*b* System, www.erx50.com).

2. MATERIALS AND METHODS

2.1 Cheese samples

Refer to Chapter 3.

2.2 Colour analysis

Approximately 300 g of a block of each cheese was trimmed by one cm on all sides to eliminate any colour inconsistencies, due to packaging. Six measurements of CIE L* a* b* were taken at random places on each cheese, under incandescent lighting, with a Gardner Colorimeter (Colour-guide D65/10° (daylight illumination, aperture opening) 45°/0° colorimeter (Catalogue no. 6805, BYK-Gardner GmbH, Gerestried, Germany).

2.3 Statistical procedures

Analysis of variance (ANOVA) was conducted to determine mean attribute values for the respective samples across replicates of the same cheese. The data were analysed using SAS® software (Version 9; SAS Institute Inc, Cary, USA). Student's t-least significant difference (LSD) was calculated at the 5% significance level to compare treatment means. Pearson's correlation analysis was conducted to determine whether linear relationships existed between the colour of the cheese sample and descriptive sensory attributes.

3. RESULTS AND DISCUSSION

ANOVA results determined significant differences between the treatment means for all of the colour readings at a significance level of 5%. The mean colour scores and their least significant differences for the six samples of cheese are listed in Table 1.

As the only uncoloured sample, it was expected that mean values for the Edam sample would be significantly different from the other cheese samples. This cheese received the highest mean values for L* and the lowest for both a* and b*. The cheese could be described as off-white, with a low level of red and yellow shades. Mean values for the Gouda and Cheddar sample at 15 months maturity were the same ($p>0.05$). These two samples could be described as less white than Edam, with a higher level of both red and yellow shades. The remaining three samples, the Cheddar cheeses at 4, 8 and 32 months, received the same mean values for the respective colour attributes. These samples could be described as less white than the Gouda and Cheddar at 15 months, but with a higher level of red and the same level of yellow shades.

In a factory environment, recipes and manufacturing processes are standardised to ensure consistent quality in the final product. For this reason, the Cheddar cheese samples should have received the same readings for colour, as they were all made according to a set recipe. However, Lucey *et al.* (2003) suggested that milk composition may influence the final colour of a cheese. Furthermore, in his 20 year career in cheese production at Parmalat SA (Pty) LTD, Danie Malette, has found that Cheddar cheese with a low pH tends to present a whiter colour than cheese with a slightly higher pH (personal communication, 2012). The Cheddar sample at 15 months was significantly whiter than the three remaining Cheddar samples and recorded a lower pH than the

other Cheddar samples. The pH of this cheese was 5.02, compared with 5.21, 5.32 and 5.24 for the Cheddar samples at 4, 8 and 32 months maturity, respectively. The effect of pH on colour in cheese, however, has not been reported in literature to support this observation.

Table 1 Mean colour scores of the CIE L* a* b* results for each of the six cheese samples.

	L*	a*	b*
Treatment	[2]Mean	[2]Mean	[2]Mean
Gouda	75.68[b]	16.00[b]	42.32[a]
Edam	81.80[a]	3.23[c]	33.87[b]
Cheddar 4mo	72.92[c]	16.84[a]	43.70[a]
Cheddar 8mo	73.34[c]	16.99[a]	43.13[a]
Cheddar 15mo	75.79[b]	16.02[b]	42.82[a]
Cheddar 32	72.99[c]	17.30[a]	43.47[a]
[1] LSD	**1.15**	**0.71**	**1.38**

[1] Least Significant Difference (p=0.05)

[2] Values with the same superscript are not significantly different

3.1 L* Value

The L* measures the luminosity or whiteness of a sample from 100 to 0, where 100 is white and 0 is black (Figure 1). Mean readings in Table 1 for L* ranged from 72.92 to 81.79, indicating that the six treatments reflected high levels of white on the CIE L*a*b* colour scale. No progressive change in L* was observed as the cheeses aged, and neither did L* differentiate the cheeses by age (Figure 2). As the only uncoloured cheese, Edam received the highest reading for L*. The Cheddar sample at four months received the lowest score for L*. Interestingly, scores for Gouda and the Cheddar sample at 15 months were not significantly different from one another. This implies that although the two samples differed in age by 14 months, both cheeses presented the same degree of luminosity or white colour. The Cheddar samples at 4, 8 and 32 months respectively did not differ significantly from one another in readings for luminosity.

Investigation of the correlation analysis revealed significant ($p<0.05$) positive relationships between L* and buttery ($r = 0.915$) and creamy ($r = 0.959$) aroma. These aromas are generally associated with young and undeveloped flavours (Drake, McIngvale, Gerard, Cadwallader, and Civille, 2001; Drake, Gerard, Wright, Cadwallader, and Civille, 2002). Rubbery texture was also positively correlated with L*. Negative correlations were identified with a* ($r = -0.953$), b* ($r = -0.959$) and fat ($r = -0.965$). Results from this investigation suggest a strong relationship between lighter coloured

cheeses and young, undeveloped flavours. Furthermore, the lighter coloured cheeses tended to have a more rubbery texture and lower fat content.

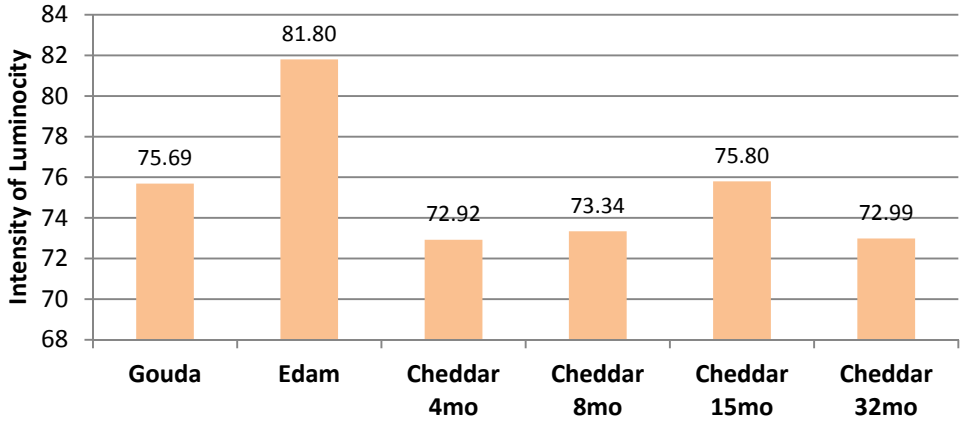

Figure 2 Luminosity (the degree of lightness measured from white to black) results for the six cheese samples**.**

3.2 a* Value

The a* value defines the hues from red (positive values) to green (negative values). Scores ranged from 3.23 to 17.30 suggesting that the samples were redder in hue (Table 1). No progressive change in a* was observed as the cheeses aged, and neither did a* differentiate the cheeses by age (Figure 3). Since the Edam was the only uncoloured cheese sample, it was anticipated that it would receive the lowest a* reading. Gouda and the Cheddar sample aged to 15 months were not different from one another ($p>0.05$) indicating the same degree of red hue in both cheeses. The samples at 4, 832 months maturity were also not significantly different from one another suggesting the same red hue ($p>0.05$).

Investigation of the correlation analysis revealed positive relationships with b* ($r = 0.997$) and fat content ($r = 0.957$). Negative correlations were identified between a* and butter aroma ($r = -0.923$), creamy aroma ($r = -0.989$), rubbery texture ($r = -0.975$) and L* ($r = -0.953$). These results suggest that the red hued cheeses tended to be older with a higher fat content as the levels of buttery and creamy aroma and rubbery texture, commonly observed in young cheeses (Drake *et al.,* 2001), were generally lower.

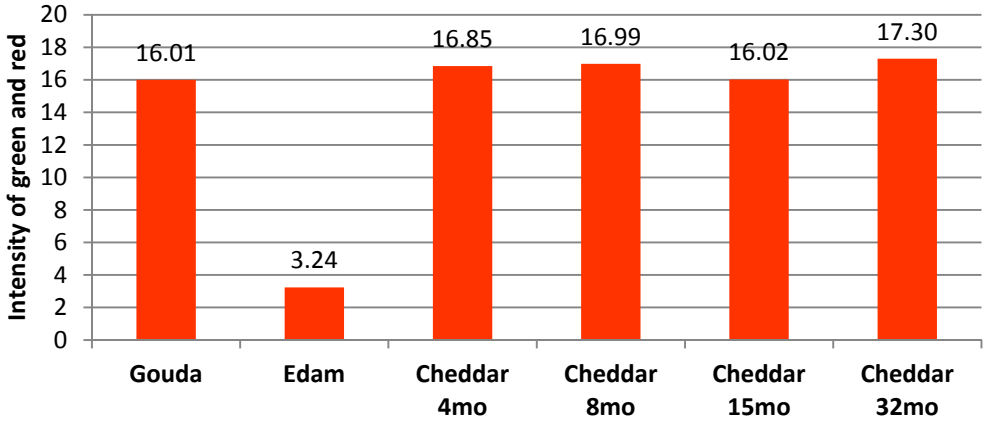

Figure 3 Results for a* indicating degree of green (-) and red (+).

3.3 b* Value

The b* value defines the shades from yellow (positive values) to blue (negative values). Scores ranged from 33.87 to 43.70 suggesting that the samples tended to have a yellow shade (Table 1). There was no progressive change in b* as the cheeses aged and neither did b* differentiate the cheeses by age (Figure 4). As the only uncoloured cheese, it was expected that the Edam sample would receive the lowest score for b*. Scores for the remaining cheese samples were not significantly different from one another suggesting that they were all of a similar yellow shade ($p>0.05$).

Investigation of the correlation analyses identified a positive relationship with a* ($r = 0.997$) and fat content ($r = 0.964$). Negative correlations identified included butter aroma ($r = -0.921$), creamy aroma ($r = -0.984$), rubberyness ($r = -0.981$) and L* ($r = -0.959$). Butter and creamy aromas are generally associated with young cheese flavours (Drake *et al.*, 2001; Drake *et al.*, 2002). A young curd is also considered rubbery (Lucey *et al.,* 2003). These results suggest that the more yellow the cheese, the higher the level of fat and degree of red hue. While a reduced level of yellow shade indicated the flavour development of a younger cheese with less whiteness.

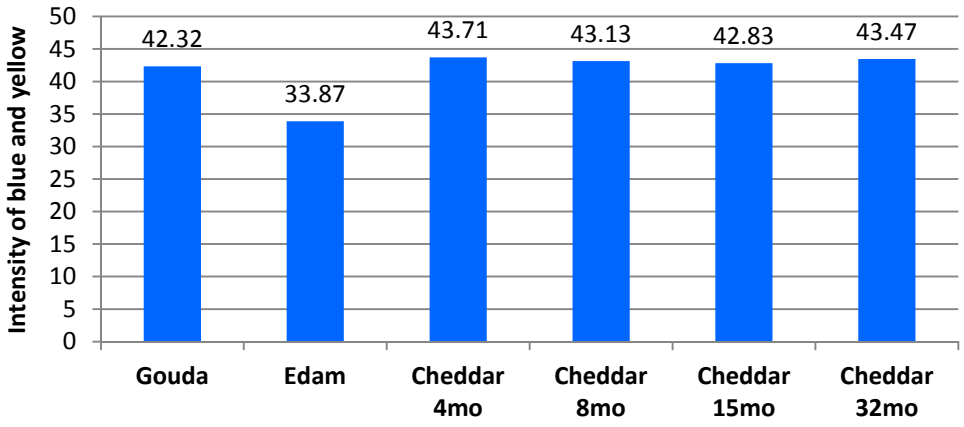

Figure 4 Results of b* indicating degree of blue (-) and yellow (+).

4. CONCLUSIONS

Instrumental analysis of cheese colour provided rapid and reliable readings for each of the six samples. Results of the analysis revealed that colour did not differentiate the cheese samples by age and neither did colour of the samples change as the cheese aged. Results for the Gouda and Cheddar sample at 1 and 15 months maturity, respectively, indicated that they were significantly the same in their L*, a* and b* values, suggesting that these two cheeses were the same colour. Cheddar samples at 4, 8 and 32 months received the same readings for L*, a* and b* suggesting that cheeses were the same colour. Naturally, as an uncoloured cheese, the Edam sample received the highest reading for whiteness and the lowest for a* and b*. Milk composition and pH may or may not have had an influence on cheese colour. No correlation was identified between pH and colour in this study and neither is there literature to support this observation. Data regarding milk composition was unavailable.

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CHAPTER 5

EXPLORING CONSUMER ATTITUDES TOWARDS CHEDDAR CHEESE

1. INTRODUCTION

The focus group technique is a qualitative research method that collects data through group interaction on a topic determined by the researcher (Morgan, 1996). The technique's strength lies in exploring what people have to say and provides insights into the origin of complex behaviours and motivations. The focus group is useful for investigating people's knowledge and experiences and can be used to examine not only what people think, but why they think that way (Kritzinger, 1995). Focus groups are used for clarification of problems and consumer perspectives, as well as for identifying opportunities and generating ideas (Lawless and Heymann, 2010). The focus group process facilitates exploration and clarification of people's views, in a way that would be less easily accessible in a one-to-one interview (Kritzinger, 1995). Resulting from this flexibility, issues that are not expected can be followed up immediately (Lawless and Heymann, 2010).

Reliability of this technique is determined by the common themes that begin to emerge and are repeated in subsequent groups. Additional groups of consumers usually yield similar information. Validity is determined by the relevancy of the information to the wider population (Lawless and Heymann, 2010).

According to Sudman and Blair (1998), the advantages of focus group advantages are: a lower cost per person when compared to in-depth interviews; a possible stimulating effect from group interaction; and effective documentation of human perception since the focus groups are observed and recorded. The disadvantages of this method include: less information obtained from each respondent; less flexible regarding the use of physical stimuli such as pictures; and less complete at the individual level, as many participants may not comment on a given issue discussed by the group.

Bogue, Delahunty, Henry and Murray (1998) approached new product development from a multi-functional methodology, combining marketing and sensory analysis to identify desirable attributes of Cheddar-type cheese. Five focus groups representing different socio-economic groups were selected to explore the influences on preferences and purchase behaviour. Members of each focus group were asked to complete a questionnaire, and to taste and rate eight treatments of cheese. The authors reported that implicit attitudes and beliefs were recognised and expanded upon as a result of the social interaction of the focus group. In general, these authors found that participants preferred mature Cheddar-type cheese, however, tended to purchase mild Cheddar

cheese as it was cheaper and more appropriate for everyday use. One group, consisting only of females, first considered their children's taste before purchasing cheese. Three of the five groups consisting of postgraduate, young professionals and older professionals respectively, would not consider purchasing anything other than conventional Cheddar-type cheeses, that is, they would not consider purchasing reduced fat and vegetarian cheese.

As part of a conjoint analysis of consumer preferences for farmhouse cheese, Murphy, Cowan and Meehan (2004) utilised information from a focus group to examine the "ideal" characteristics of Irish Farmhouse cheese. The three focus groups differentiated attributes of flavour, texture, price, nutritional and other information, pasteurisation, packaging, colour of cheese and weight. The focus group provided vital information on relevant product attributes, specifically those influencing consumer preference. The ideal farmhouse cheese profile was one with a strong flavour, hard texture, packaged in wax, produced with pasteurised milk, white in colour and with nutritional information printed on the packaging.

In their study to determine consumer perception of fat reduction in cheese, Childs and Drake (2009) conducted six focus groups with women between 25 – 50 years of age. The individuals were selected specifically because they were the primary shoppers of the household. Subjects were asked to discuss their consumption habits of cheese, attitudes on health and the types of cheese purchased. Attitudes on flavour and texture of lower fat cheeses were also probed. Key points arising from the focus groups included health issues, labelling, the negative aspects of lower fat cheese flavour and texture, and pricing.

The benefits of conducting and extracting information from a focus group are explained by Lawless and Heymann (2010), who suggest that a focus group panel can characteristically encapsulate and reflect the perception of the target population for a specific product with reasonable probability. Attention is therefore on the quality of information gained and not on reaching a consensus decision within the group.

The primary objective of this focus group study was to gain a greater understanding of consumer attitudes towards cheese *per se* and to explore those aspects influencing purchase intent. A secondary objective was to obtain consumer opinion on the six types of cheese.

2. MATERIALS AND METHODS

2.1 Cheese Samples

Refer to Chapter 3.

2.1 Focus group

Two groups of eight consumers each, male and female aged between 24 and 55 (average age 45) and from the Western Cape, South Africa were recruited to discuss their attitudes towards cheese and their opinion on six types of cheese. All participants consumed hard and semi-hard cheese every day or every other day. The focus group sessions were conducted on 31st March and 1st April 2010, respectively. Information was obtained by taking the group through a series of informal questions. The questionnaire was used by the facilitator and not handed out to each member. The group members were asked to consume six types of cheese and comment on the attributes of appearance, aroma, flavour and texture. Panel members were also asked to score the overall acceptability of the different cheese samples using a 10-point scale (Table 1) where 1 = *Inedible Quality* and 10 = *Excellent quality* (Lawless & Heymann, 2010).

Table 1 Quality assessment scale with sores to determine eating quality of the cheese samples.

1	2	3	4	5	6	7	8	9	10
Inedible Quality	Very Poor Quality	Poor Quality	Slightly Poor Quality	Acceptable Quality	Satisfactory Quality	Fairly Good Quality	Good Quality	Very Good Quality	Excellent Quality

3. DATA ANALYSIS

Data generated from the focus group were transcribed and coded. Responses to the moderator's questions were noted by observers and key points, mentioned by at least two thirds of each focus group were recorded. Mean values for appearance, flavour, texture and overall eating quality were calculated for each of the six cheese samples.

4. RESULTS AND DISCUSSIONS

The outcome of the focus group probing consumer attitudes and aspects influencing cheese selection and purchase, are summarised in the following paragraphs. The quality scores for appearance, flavour and texture for the six cheeses types are summarised in Table 2.

4.1 Factors influencing purchase intent

Flavour remains the principal factor driving cheese selection and purchase. Functionality and end-use application, together with value for money, follow in importance and finally, despite its acknowledged high fat content, cheese is considered a healthy food option. Convenience and packaging play only a minor role in the decision making process.

Participants in this focus group purchased cheese for its flavour attributes. Mature cheese, high in flavour intensity was purchased for special occasions such as a cheese platter while mild flavoured cheese was purchased for everyday use. Texture played an important, albeit secondary role to flavour. Some participants, however expressed a dislike of crumbly cheese. Colour did not play a substantial role in the buying decision. Participants nevertheless associated a yellow orange colour with Cheddar cheese and perceived an uncoloured cheese such as Mozzarella cheese to have less flavour. Furthermore, some participants considered white cheese a healthier dietary option. These results are in contrast to Bogue *et al.* (1999), who reported that flavour, texture and colour are all important aspects of consumer cheese choice.

Participants in this study confirmed that functionality and end-use determined the type of cheese purchased. Mature Cheddar was purchased for special occasions while mild Cheddar was selected for everyday use on sandwiches and in salads. This is supported Bogue *et al.* (1999), who state that selection and purchase of cheese is not simply a matter of taste preference, but rather of functionality as well.

Cheese was considered an expensive food item and participants looked at price per kilogram as part of the buying decision. This group would, however, be willing to pay more for a mature cheese with greater flavour intensity and less for a mild cheese for everyday use. This compares favourably with Mintel (2009a) and Mintel (2009b) which state that consumers, under economic pressure, are reassessing their purchasing decisions. When buying cheese, price and value for money are becoming the most common factors determining choice.

Although consumers worldwide have been encouraged to improve their diet and address issues of heart disease, obesity and diabetes (Mintel, 2009a; Mintel, 2009b and Sloan, 2007), participants in this focus group did not consider cheese an unhealthy product. Most believed that cheese was healthy, natural and a source of calcium. Few negative health concerns were raised. Participants appreciated the high fat content of cheese; however stated that they would rather reduce their intake of cheese than consume a low fat option. This confirms reluctance to compromise on flavour with reduced fat alternatives (Mintel, 2009a; Mintel, 2009b). Consequently, it is understandable that Euromonitor (2008) reports healthier cheeses remain a niche market in South Africa. Furthermore and in contrast to the observations made in this focus group, Bogue *et al.* (1999) reported that although consumers considered cheese a nutritious product with a good source of protein and calcium, its high fat content negated these positive attributes. Childs and Drake (2009) reported that consumers in their study could identify the benefits of lower fat cheese

in reducing cholesterol and calorie intake, however, they found the flavour and texture of reduced fat cheeses objectionable when compared with a full-fat cheese. In this study, participants who would purchase a low fat cheese would do so for family members with cholesterol problems.

Participants liked the idea of cheese blocks packaged in a re-sealable bag. Grated cheese was considered expensive, too crumbly and some participants questioned its origin. In general, they did not like the flavour of cheese slices as the taste reminded them of processed cheese. Consumers felt that there was a limited use for cheese slices. Some consumers, however, did like the real cheese slices, but only for specific occasions such as camping and hiking. Sliced cheese was therefore not part of everyday cheese consumption. Consumers normally bought blocks of cheese and stated that a 250 – 300 g block was a convenient size of packaging. Some consumers preferred cheese with a wax layer as this reduced the drying out of the cheese while other consumers felt that this was old fashioned and they did not like the waxy layer. They did, however, think that black wax on mature Cheddar looked interesting.

4.2 Consumption behaviour of cheese

The majority of participants bought mild Cheddar for everyday use and mature Cheddar for specific occasions such as a cheese platter, wine tasting and for entertaining or as part of an ingredient for a special meal. Only a limited number of consumers bought low fat cheese and generally participants confirmed that they would rather reduce their daily consumption of cheese than consume a low fat option.

Cheddar cheese was mainly used on sandwiches, as a topping for baked dishes, in salads and as a snack. The majority of participants purchased cheese in block form. Consumers avoided ready-packed cheese slices as these were regarded as expensive and would only purchase sliced cheese if in a hurry. One or two consumers bought cheese spread, but only when making sandwiches for a large group of people. Consumers used a variety of cheese and the following were identified: Brie, Camembert, Feta, Gouda, creamy Blue, Mozzarella, and Goat's milk cheese, Pecorino, Parmesan, Mascarpone, Gruyere and Ricotta. For everyday use, consumers would normally buy Cheddar, Gouda and Feta cheese.

4.3 Brand awareness of Cheddar cheese

Brand selection was mainly influenced by price; however, participants were aware of brand names of Cheddar cheese. Consumers mostly bought Parmalat, Clover, Ladismith cheese, Dairybelle and Woolworths Cheddar cheese. It was clear that the discerning cheese consumers were particular about the brand of cheese and level of maturity they purchased.

4.4 Consumer acceptance and comments for the six cheese variants

Overall eating quality results suggest that participants in both focus groups preferred the intensely flavoured older cheeses and disliked the uncoloured reduced fat Edam. Results displayed in Table 3 and Figure 1 indicate that Cheddar at 32 months maturity received the highest score for overall eating quality, followed by Cheddar matured to 15 and 8 months, respectively. Edam received the lowest score for overall eating quality. Aroma and flavour scores followed a similar trend to the overall eating quality. Gouda received the highest score for appearance, followed by the uncoloured Edam and Cheddar at 15 months maturity. Cheddar cheese matured to 32 months received the lowest score for appearance. Cheddar cheese at 15 and 32 months maturity both received the highest score for texture, followed by Cheddar at 4 and 8 months maturity. Edam received the lowest score for texture.

Table 2 Averaged scores for appearance, flavour and aroma, texture and overall eating quality of the six cheese samples using the Quality Assessment Scale.

Sample Description	Appearance	Flavour & Aroma	Texture	Overall eating quality
Gouda	7.5	7.1	6.9	7
Edam	7.3	6.6	6.7	6.8
Cheddar 4 months matured	7.1	7.3	7.6	7.2
Cheddar 8 months matured	7.3	7.5	7.6	7.8
Cheddar 15 months matured	7.1	7.6	7.9	7.9
Cheddar 32 months matured	7.0	7.7	7.9	8.3

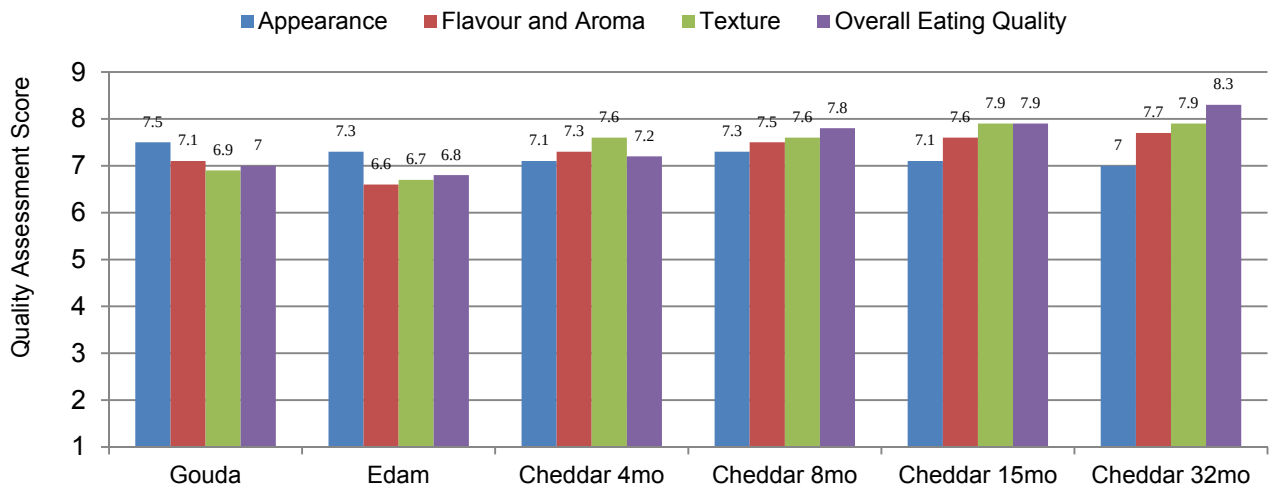

Figure 1 Averaged scores for the eating quality of the six cheese samples.

Gouda Participants appreciated the appearance of this cheese. The cheese had a smooth, creamy and moist appearance. It was lighter orange than the Cheddar cheese samples and considered a typical Gouda cheese colour. Consumers found the even colour very acceptable. The aroma and flavour were characteristic of a Gouda cheese and described as creamy and milky. When compared with the flavour of Cheddar cheese, however, the Gouda was considered bland. Some consumers found the saltiness acceptable, while others felt the cheese was not salty enough. Some participants described the texture of the Gouda as creamy while others felt that it was slightly rubbery.

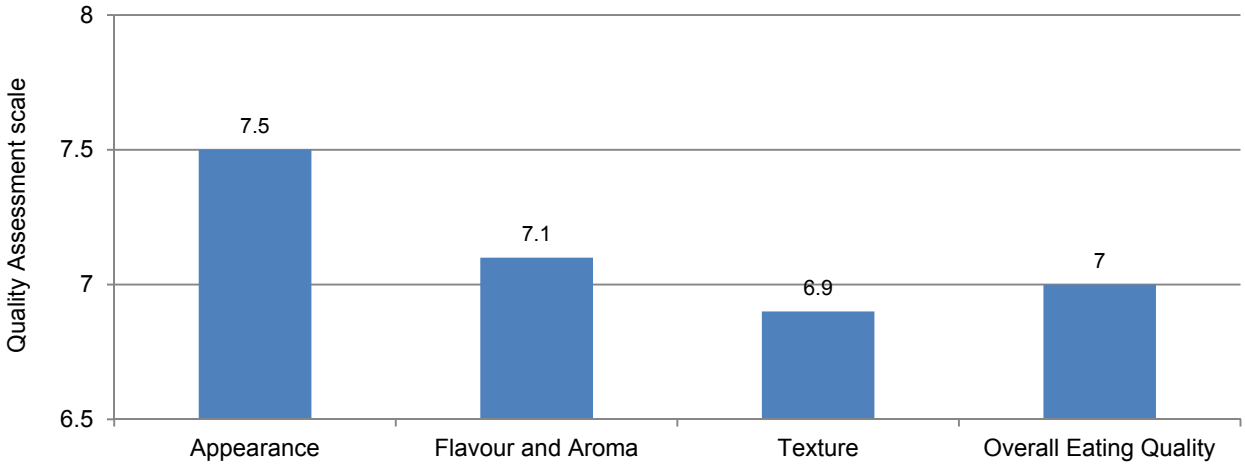

Figure 2 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Gouda cheese.

Edam Only a few participants were partial to the Edam as they regarded the white cheese a healthier food option. A general perception amongst the group, however, was that white cheese tended to be rubbery and less appetising than yellow-orange cheeses. Participants furthermore said that they would only buy white cheese if the quality was better and the flavour closer to that of orange coloured cheese. The aroma and flavour of the Edam cheese was perceived as softer than that of the Gouda. The cheese was described as too salty. A number of participants felt that the Edam texture was slightly rubbery and it was described as more Gouda-like than Cheddar-like. As a reduced fat cheese, however, participants felt that the Edam texture was good and would consider purchasing in the future.

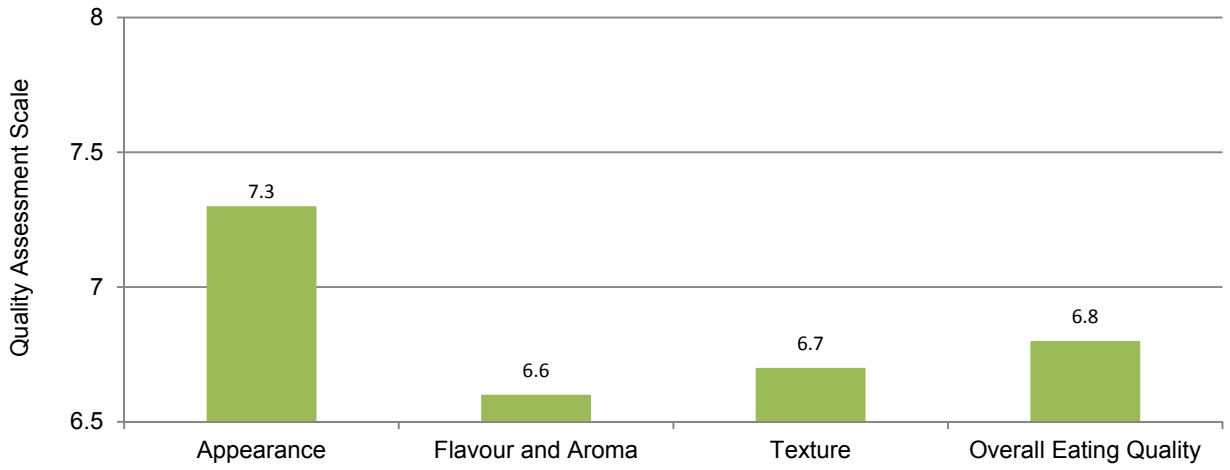

Figure 3 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Edam cheese.

Cheddar cheese matured to 4 months Participants associated a yellow-orange colour with Cheddar cheese. Some participants thought this cheese had a cracked appearance describing it as having been frozen. The cheese, however, did not display as many cracks as the Cheddar samples matured to 8 and 32 months. Consumers described the flavour of this cheese as typical of a young Cheddar, reminding them of the commercial variant, Melrose cheese. The 4 month mature Cheddar was further described as soft in flavour and suitable for everyday use. This cheese, however, was deemed too bland for consumers who preferred a more mature cheese. The texture, described as the softest of the four Cheddar cheese samples, held its shape and did not crumble. Participants remarked that this sample met with their expectation of an everyday Cheddar cheese texture.

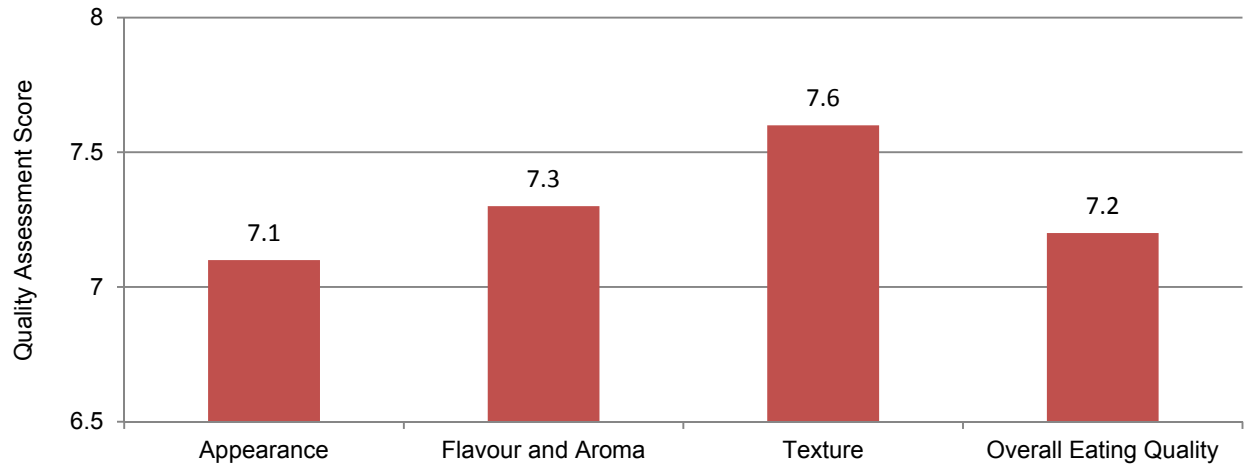

Figure 4 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Cheddar cheese matured to 4 months.

Cheddar cheese matured to 8 months Although this cheese fell within participants expectations of a yellow-orange colour, it had a slightly darker and drier appearance, with observable cracks and visible white spots on its surface. Consumers indicated that this gave the impression of a more mature cheese. They felt that the dry appearance would give rise to a crumblier cheese texture and some participants felt that this would look messy on a cheese platter. Consumers described the aroma and flavour of this cheese as a typically rich, almost sharp, savoury mature Cheddar cheese. For some, the aroma and flavour were too strong and many felt that this cheese displayed a stronger flavour than the Cheddar matured to 15 months. This cheese was described as creamy and slightly crumbly. Some participants felt that this was the crumbliest of all four Cheddar cheeses. Generally, consumers expected an older Cheddar to be crumbly.

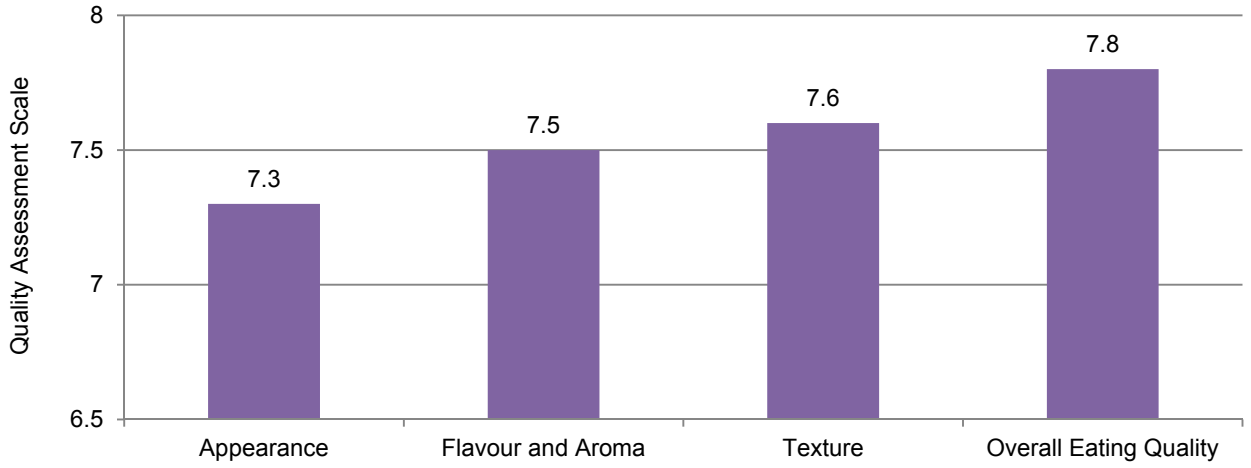

Figure 5 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Cheddar cheese matured to 8 months.

Cheddar cheese matured to 15 months The colour of this cheese fell within participant expectations of a Cheddar cheese and was considered acceptable. The aroma and flavour of this cheese was described as full-bodied and typical of a mature Cheddar. The majority of participants found the aroma and flavour of this treatment less strong, softer and more subtle than that of the eight month mature sample. The texture was described a creamy and slightly crumbly, but still soft.

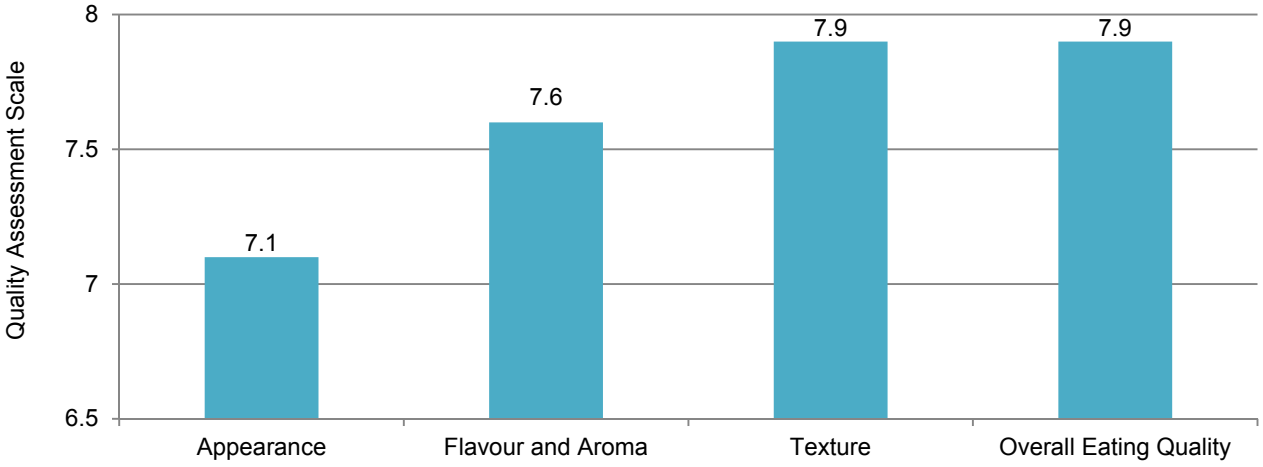

Figure 6 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Cheddar cheese matured to 15 months.

Cheddar cheese matured to 32 months The yellow-orange colour of the cheese fell within participant expectations. The cheese, however, was slightly darker than the other Cheddar samples. Participants commented that visible white spots on the surface were indicative of a mature cheese. The aroma and flavour were described as very pleasant and highly acceptable, with a slight sweetness and good lingering Cheddar cheese flavour. The aroma and flavour aspects of this Cheddar cheese fell within consumer expectation of a mature Cheddar cheese. The texture of this cheese was characterised as creamy and smooth and highly acceptable to participants in the focus group.

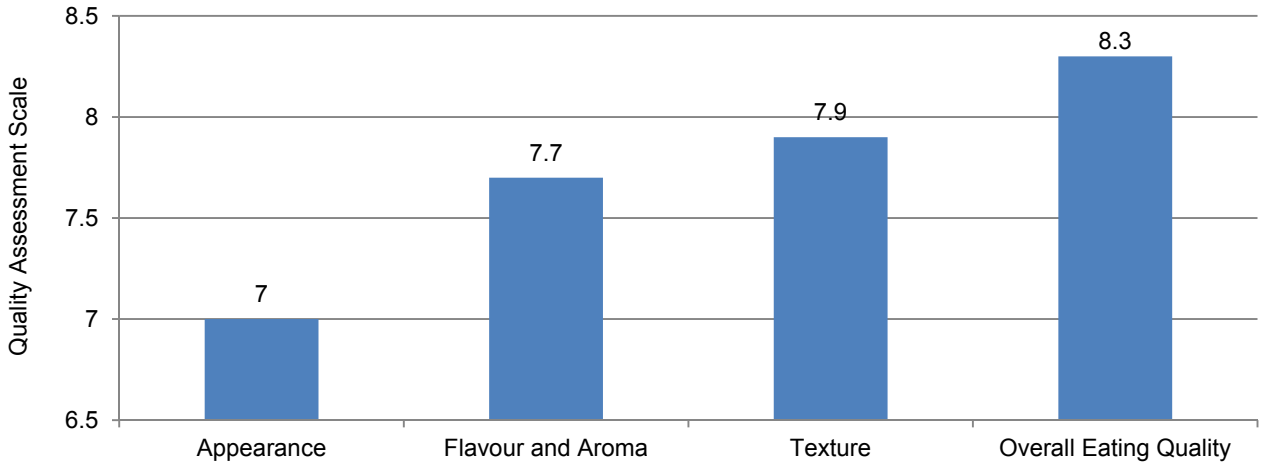

Figure 7 Quality scores for appearance, flavour, aroma, texture and overall eating quality of the Cheddar cheese matured to 32 months.

5 CONCLUSIONS

The purpose of this study was to determine the general perceptions of the South African consumer regarding Cheddar cheese. Two focus groups, through group interaction and discussion, explored the reasons behind consumer selection and purchase of cheese. Consumer attitudes and behaviour towards cheese was further examined and clarified. Insight into consumer opinion, based on the consumption of six types of cheese, was explained and documented.

Flavour remains the most important factor determining selection and purchase intent of cheese, functionality and end-use application together with value for money follow. Despite its high fat content, cheese is still considered a healthy food choice. Finally, packaging and convenience play only a minor role in the buying process.

Participants in the two focus groups indicated a strong preference for mature, intensely flavoured cheese. In addition, they indicated a dislike of mild cheese texture, although the appearance of the younger cheeses was highly appreciated. A general expectation was that Cheddar cheese should be a yellow-orange colour. Colour, however, did not play an important role in the buying decision. White cheese was only purchased for family members with high cholesterol problems. Cheese was considered good value for money although the price per kg was noted and participants compared brand offerings. Participants considered cheese a healthy food and most would rather reduce their daily intake of cheese than buy a low-fat alternative and compromise on flavour. Mild Cheddar was purchased for everyday use while mature Cheddar cheese was selected for special occasions. Participants in the focus group preferred purchasing cheese in a block form and seldom bought grated or sliced cheese as this type of packaging was considered expensive.

The flavour and texture characteristics of the Gouda and Edam samples differed from those of the four Cheddar samples. Participant attitudes towards the cheese samples also varied. In general, however, the four month matured Cheddar sample was considered the most appropriate for everyday use while the mature samples were highly appreciated and would be considered for use on special occasions. The four month mature Cheddar was described as mild with a highly satisfactory colour. The mature Cheddar samples were characterised by a lingering Cheddar cheese flavour, crumbly texture and visible white spots.

Results from the focus group highlighted the necessity to conduct an in-depth consumer preference study to further understand consumer attitudes and acceptance of cheese.

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CHAPTER 6

OPTIMISING CHEDDAR CHEESE FLAVOUR TO SATISFY CONSUMER SENSORY REQUIREMENTS

1. INTRODUCTION

Consumer liking of a product is an integrated response and influenced by factors that include sensory ability, past experience, expectation and place of consumption (Delahunty and Drake, 2004). Furthermore, consumers differ in their sensory perception and communication thereof as a result of physiological, psychological, social and cultural differences (Delahunty and Drake, 2004).

If sensory quality is the ultimate measure of product quality and market success (Drake, 2007), then optimizing the sensory aspects of that product based on the consumer acceptance of the product should be the aim of every food manufacturer (McEwan, 1996). There is a distinct advantage and ensured profitability for a company that can consistently optimize a product to satisfy consumer sensory requirements (McEwan, 1996; Murray and Delahunty, 2000a).

Recognizing the influence of cheese flavour on consumer acceptance and determining the point at which consumer acceptance would be greatest, poses a challenge to Cheddar cheese marketers (Lawless and Heymann, 2010; Stone and Sidel, 1993). Equally so, recognizing those production or maturation variables which may be altered to modify Cheddar flavour to ensure greater consumer acceptance, pose a challenge to Cheddar cheese producers (Lawless and Heymann, 2010).

Consumer or affective tests seek to quantify the degree of liking for a product with an aim of further understanding consumer responses to a product (Drake, 2007). During these tests, target consumers are presented with products and asked to indicate degree of liking on a scale. The most common scale used is the nine-point hedonic, which appropriates the psychological states of “like” and “dislike” on a linear scale. For each hedonic description along the 9-point scale, a numerical value ranging from 1 (dislike extremely) to 9 (like extremely) is assigned successively (Gacula, Singh, Bi and Altan, 2009).

Young, Drake, Lopetcharat and McDaniel (2004), using the nine-point hedonic scale and evaluating seven samples of Cheddar cheese, determined that consumers could distinguish between “young” and “aged” cheese flavours. Moreover, these results were consistent with descriptive sensory analysis. Based on results for Cheddar cheese intensity, the authors were also able to establish that the Cheddar cheese flavour concept varied amongst consumers.

Consumers indicated that both young flavoured and aged flavoured Cheddar cheese samples were associated with high Cheddar cheese intensity. Caspia, Coggins, Schilling, Yoon and White (2006) asked consumers to indicate their liking of three cheeses on a nine-point hedonic scale. Since the means obtained for overall flavour acceptance were very similar to those obtained for overall liking, the authors were able to conclude that consumer liking of a product is based on flavour. Bogue, Delahunty, Henry and Murray (1999) confirmed in their study that having received the lowest mean score of 3.89 (dislike moderately); reduced fat cheese was the least acceptable cheese to consumers. Murray and Delahunty (2000a) also found that consumers in their study did not like reduced fat cheese. This cheese received a mean score of 4.6, compared with 6.7 for the most preferred cheese.

Traditional market research and sensory test methods that rely on averaged preference data may not, however, optimise preference for the majority of consumers. Since preference mapping has the ability to define the most favourable or "optimal" product for consumer segments, it provides an advantage to researchers aiming to better understand consumer acceptance (Murray and Delahunty, 2000a).

Preference mapping techniques assist in determining those sensory characteristics that drive consumer acceptance. Lawless and Heymann (2010) confirm that preference mapping provides valuable information about each consumer's acceptance in a visual format. The technique provides an image of the association between a product, its sensory attributes and consumer preferences (Murray and Delahunty, 2000a; Murray and Delahunty, 2000b; Young *et al.,* 2004; Caspia *et al.,* 2006; Drake *et al.*, 2008). The method requires an objective characterisation of a product's sensory attributes, achieved by descriptive sensory analysis (DSA) , which is then related to preference ratings for the product obtained from a representative sample of consumers (Murray and Delahunty, 2000a).

Partial least-squares mapping is a direct application of partial least-squares regression. As a preference-mapping tool, the dependent (*y*) variables in the PLS model are the overall liking ratings of the consumers and the independent (*x)* variables are the sensory attribute ratings. Since PLS can handle multiple dependent variables in the same model, the overall liking ratings of the total respondent base, as well as those of any consumer segments of interest, can be fit in a single analysis. This is helpful for determining the similarities and the differences in the attributes that drive liking among the segments (Meilgaard, Civille and Carr, 2007). The approach also provides information on consumer segmentation, allowing the company to targets its product appropriately (McEwan, 1996).

Several international studies have been published, combining preference mapping techniques and Cheddar cheese (Murray and Delahunty, 2000a; Murray and Delahunty, 2000b; Young *et al.*, 2004, Caspia *et al.*, 2006; Drake *et al.*, 2008; Drake *et al.*, 2009).

Since consumer acceptance of cheese is variable (Young *et al*., 2004), the aim of this study was to determine at what point Cheddar cheese flavour could be optimised to improve consumer acceptance and ultimately consumption. Descriptive sensory data characterising the appearance, aroma, flavour and texture of six types of cheese with varying degrees of maturity together with the consumer acceptance data for colour, texture, flavour and overall liking of the six cheese samples were investigated through application of PLS. Hierarchical cluster analysis was also performed on the data to determine clusters of consumers with similar acceptance behaviour. Analysis of variance was conducted on each of the variables separately (colour, texture, flavour and overall liking). The results provided information on the consumer preference per cluster. Rather than looking at demographics and then at levels of consumer acceptance, PLS regression offered an alternative way of examining consumer acceptance. PLS was performed on each cluster in an attempt to relate the clusters to the socio-demographic and attitudinal data collected from the consumer questionnaire. Consequently consumer acceptance was identified and based on these results, demographic and attitudinal behaviour were further investigated to define the clusters more specifically. As a result, areas where Cheddar cheese could be optimised to satisfy specific consumer sensory requirements were identified.

2. MATERIALS AND METHODS

2.1 Cheese samples

Six commercial cheeses manufactured in the Western Cape, South Africa were supplied for the consumer acceptance analysis. Cheeses were selected according to age and encompassed a broad range of maturity levels varying from 1 and 2 months for the Gouda and Edam cheeses to 4, 8, 15 and 32 months respectively for the Cheddar cheeses. Cheeses were produced with pasteurised milk and all except for the Edam cheese were coloured. Nine kilograms of each cheese was delivered from a central point to the sensory research facility, Department of Food Science, University of Stellenbosch on 25th March 2010 where they were stored in the dark and at 6°C until analysis. Consumer acceptance testing took place one week after descriptive sensory analysis of the cheeses.

2.2 Consumer acceptance testing

The cheeses were tested in a single session and presented individually in a randomized balanced order. The cheeses were removed from the refrigerator 1 h prior to the consumer testing and tempered to room temperature of approximately 19°C. Cheeses were cut into ~10 g blocks and dispensed into glass ramekins numbered with 3-digit codes. Consumers (n = 115), recruited from the university students and staff, were provided with a screener and scoring ballot. The screener was designed for collecting socio-demographic information and evaluating consumer opinions for

cheese and cheese products. The scoring ballot was used to assess consumer degree of liking of the cheese for colour liking, texture liking, flavour liking and overall liking using a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely (Lawless and Heymann, 2010). Consumers also rated degree of liking for different types of cheese where 1 = dislike extremely and 9 = like extremely; how cheeses were consumed where 1 = seldom and 9 = often and finally, aspects of purchasing where 1 = not important to 9 = extremely important. Consumers were provided with water and unsalted biscuits for palate cleansing. Responses were collected using scoring sheets. Consumers were provided with 300 g of commercial Cheddar cheese for their participation. (Addendum 1).

2.3 Descriptive sensory analysis and instrumental analyses

See Chapters 3 and 4 for methodologies applied for descriptive sensory analysis (DSA) and instrumental colour analysis, respectively.

2.4 Statistical analysis of data

Data was collected in spread sheets using Microsoft Excel 2007. Statistical analyses were performed using XLSTAT 2007.8.03 (Addinsoft, SARL, Paris, France). Analysis of variance (ANOVA) tested the significance of each consumer opinion and acceptance at a significance level of 95% ($P<0.05$) (SAS®, Version 9; SAS® Institute Inc., Cary, USA). If the main effect was significant, Fisher's least significant test (LSD) was applied to determine the direction of the differences between mean values.

Consumer acceptability scores were segmented by agglomerative hierarchical clustering (AHC) using Ward's criterion. Thereafter PLS was performed on the data using XLSTAT 2012.4.03 (Addinsoft, SARL, Paris, France). Partial least-squares regression analyses were performed on the consumer degree of liking data, the socio-demographic and attitudinal consumer data, as well as the sensory and instrumental data, in an attempt to relate the different sets of information. Both multivariate techniques were performed, using the XLSTAT software package (Version 2012.4.03, Addinsoft, SARL, Paris, France).

3. RESULTS AND DISCUSSION

3.1 Socio-demographic data

The consumers differed in gender, age, cheese preference, consumption and factors influencing purchase intent. Of the 115 consumers that took part in the consumer acceptance testing, 62% were female, 38% male. The majority, 62%, of consumers fell between the ages of 19 to 24; 11% between the ages of 25 – 30; 10% between the ages of 31 – 35; 10% between the ages of 36 – 45

and 7% were over the age of 45. A detailed breakdown of the age groups, number of consumers and related percentage can be seen in Table 1.

Twenty-six percent of the participants consumed cheese every day, while 48% consumed every second day. The remaining 26% consumed cheese infrequently, i.e., between once a week and twice in a month.

Table 1 Details of consumer age groups and related percentages for the consumer analysis.

Age group	Number of consumers	Percentage
19 – 24	71	62
25 – 30	13	11
31 – 35	12	10
36 – 45	11	10
45 +	8	7
Totals	**115**	**100**

3.2 Consumer attitudes towards Cheddar cheese

To gain a greater understanding of consumer attitudes towards cheese, the following topics were investigated – consumer preference for a particular cheese variety, the manner in which Cheddar cheese was consumed and those aspects that influence selection and purchase of Cheddar cheese. Results are discussed below; the discussion looks at the group as a whole, then at gender and finally at age group. Since only 38% of the consumer group was over the age of 25 and too few consumers fell within each age group above 25, it was therefore decided to reduce the age group classes to ensure that enough consumers were included per class. Thus, the classes were grouped into 19 to 24 years of age and 25 years and older.

3.3 Consumer preference for a particular cheese variety

Gouda cheese was the most popular cheese amongst this group of consumers, receiving a significantly ($p<0.05$) higher score than the remaining cheese varieties (Table 2). Mild Cheddar and mature Gouda followed in preference. Low fat cheese and extra mature Cheddar were the least liked cheese varieties and this group of consumers were ambivalent towards their liking of mature Cheddar and Edam cheese. These results suggest that consumers prefer the mild and undeveloped flavours and textures of young cheese and dislike the intense flavours identified in aged cheeses. Young and undeveloped flavours include cooked milk, whey, diacetyl and milk fat (Drake, McIngvale, Gerard, Cadwallader, and Civille, 2001) and textural attributes of creamy and springy (Hort and Le Grys, 2001). Results also correspond with Young *et al*. (2004), who reported

that participants in their study consumed mostly mild cheese, followed by aged/strong flavoured cheese and finally processed cheese.

Female attitudes towards cheese preference followed a similar trend (Table 3). Gouda and mild Cheddar were indicated as the two most popular cheeses. Mature Gouda and Edam followed but to a significantly ($p<0.05$) lesser degree. Attitudes towards mature Cheddar and low fat Cheddar were ambivalent while extra mature Cheddar was generally disliked by female respondents. Gouda was also identified as the most popular cheese amongst male consumers. This was followed by mild Cheddar, mature Gouda and mature Cheddar. Attitudes towards Edam, low fat cheese and extra mature Cheddar were undecided. Of note, however, is the higher level of preference by male consumers for mature and extra mature Cheddar cheese when compared with female preference ratings. These results suggest that both males and females enjoy the mild and undeveloped flavours and textures identified in young cheeses, however, males have a greater degree of liking for the more intense flavours identified in aged cheeses.

Age groups varied in their attitudes towards preferences for different cheese varieties (Table 4). The younger group, 19 – 24 year olds, indicated an equal liking of mild Cheddar and Gouda, followed by mature Gouda. Attitudes towards mature Cheddar, Edam and low fat cheese were ambivalent. Extra mature Cheddar was the least popular cheese within this age group. The older group (25 years and older) indicated a preference for Gouda and mature Gouda, followed by mild Cheddar. Although mature Cheddar was liked, it was to a slightly lesser degree than the mild Cheddar. The older consumers were undecided on preference for Edam, low fat cheese and extra mature Cheddar cheese although results for variety preference of these three cheeses were significantly ($p<0.05$) different. Of the three, low fat cheese received the lowest score for liking. These results would indicate that the younger consumers again preferred the mild and undeveloped flavours characterising young cheese. Results also indicate that these consumers disliked the older and more intense flavours characterizing a mature cheese. Older consumers also liked the flavours of young cheeses; however, they indicated a higher level of preference for extra mature cheese than the younger group.

In contrast, the focus group results depicted in Chapter 5 indicated that the older Cheddar consumer likes mature Cheddar cheese, not for everyday use, but for special occasions. The average age of consumers in the focus group was 45.

Table 2 Mean values for indicated preference of cheese type.

Treatment	Cheese consumption
Gouda	7. 07 [a]
Mild Cheddar	6. 60 [a b]
Mature Gouda	6. 48 [b]
Mature Cheddar	5. 85 [c]
Edam	5. 82 [c]
Low fat cheese	5. 28 [d]
Extra mature Cheddar	4. 88 [d]
LSD	**0. 47**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different.

Table 3 Mean values for indicated preference of cheese for consumption by gender.

Treatment	Female consumers	Male consumers
Gouda	7. 29 [a]	6. 72 [a b]
Mild Cheddar	6. 66 [a b]	6. 51 [b]
Mature Gouda	6. 51 [b]	6. 42 [b]
Mature Cheddar	5. 55 [c d]	6. 30 [b]
Edam	6. 05 [b c]	5. 47 [c d]
Low fat cheese	5. 24 [d]	5. 36 [d]
Extra mature Cheddar	4. 49 [e]	5. 52 [c d]
LSD	**0. 68**	**0. 68**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Table 4 Mean values for indicated preference of cheese type by age group (with 1 = Dislike extremely and 9 = Like extremely).

Treatment	Age 19 - 24	Age 25 and older
Gouda	7. 25 [a]	6. 76 [a b]
Mild Cheddar	6. 75 [a b]	6. 34 [b c]
Mature Gouda	6. 25 [b c d]	6. 87 [a b]
Mature Cheddar	5. 61 [d e]	6. 25 [b c d]
Edam	5. 81 [c d e]	5. 84 [c d e]
Low fat cheese	5. 30 [e]	5. 26 [e]
Extra mature Cheddar	4. 46 [f]	5. 61 [d e]
LSD	**0. 69**	**0. 69**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

3.4 Consumer consumption of Cheddar cheese

Results in Table 5, indicating the manner of cheese consumption by consumers, suggest that participants in this study consumed Cheddar cheese mainly as sandwich filling. This was followed by cheese on biscuits, as a snack on its own or as part of a salad. The least amount of Cheddar cheese was consumed as a sauce ingredient.

Both females and males consumed Cheddar cheese most often as sandwich filler (Table 6). This was followed by eating on biscuits and then as a snack. Females included cheese more often as part of a sauce and least often as a salad ingredient. Males on the other hand indicated that they consumed Cheddar cheese in a salad more often than as part of a sauce. These results correspond in some degree with the results published by Drake *et al.* (2008). The authors indicated that 70% of the 215 respondents used mild Cheddar as sandwich filler, 51% consumed it as a snack, 68% in a salad and 88% indicated that mild Cheddar was used as an ingredient in soups and sauces.

The most popular method of consuming Cheddar cheese, across all age groups, was as sandwich filler (Table 7). This was followed by consumption of cheese on biscuits. The younger group, 19 – 24 year olds indicated that they ate cheese as a snack more often than in a salad and as part of a sauce. The older group indicated that Cheddar cheese was least often consumed as part of a sauce.

Table 5 Mean values for manner in which Cheddar cheese is consumed by total group of consumers with 1 = Seldom and 9 = Often

Treatment	Cheese consumption
Sandwich	7. 43 [a]
Biscuit	6. 39 [b]
Snack	5. 84 [c]
Salad	5. 34 [c d]
Sauce	5. 09 [d]
LSD	**0. 53**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Table 6 Mean values for the manner in which Cheddar cheese is consumed by gender with 1 = Seldom and 9 = Often.

Treatment	Female consumers	Male consumers
Sandwich	7. 29 [a]	7. 64 [a]
Biscuit	6. 41 [b]	6. 34 [b]
Snack	5. 74 [b c]	6. 02 [b c]
Salad	5. 31 [c]	5. 38 [c]
Sauce	5. 50 [c]	4. 44 [d]
LSD	**0. 78**	**0. 78**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Table 7 Mean values for the manner in which Cheddar cheese is consumed by age group with 1 = Seldom and 9 = Often.

Treatment	Age 19 - 24	Age 25 and older
Sandwich	7. 41 [a]	7. 46 [a]
Biscuit	6. 58 [b]	6. 05 [b c]
Snack	6. 00 [b c]	5. 58 [c d]
Salad	5. 51 [c d]	5. 05 [d e]
Sauce	5. 39 [c d]	4. 55 [e]
LSD	**0. 79**	**0. 79**

[1]Least Significant Difference (p = 0.05);

[2] Values with the same superscript are not significantly different

3.5 Factors driving consumer purchase intent of Cheddar cheese

Overall responses suggested that flavour, followed by price were the two most important factors driving purchase intent (Table 8). These two factors differed significantly ($p<0.05$) from each other in importance, as well from the other factors. Convenience played an important role, however, to a lesser degree. Consumers were undecided regarding packaging and brand and indicated that these two aspects were neither important nor unimportant. Fat content and nutritional offering of the cheese were not key aspects in the purchase decision. Results published by Young *et al.* (2004) followed a similar trend. Respondents indicated that flavour followed by price were the two main factors driving purchase intent. This was followed by texture, health and availability. Drake *et al.* (2008), on the other hand, suggested that availability of cheese influenced purchase intent, followed by price, flavour, brand and packaging. The focus group results depicted in Chapter 5 indicated that despite the high fat content of cheese, the majority of consumers still regard cheese as a healthy option.

Female and male responses were of a similar nature (Table 9). Flavour, followed by price, was the most important driver in Cheddar cheese purchase. Both female and male respondents indicated that convenience was important, however, to a lesser degree than price. Respondents were ambivalent towards packaging and males, in particular, towards brand, indicating that it was neither important nor unimportant. Females indicated that brand, fat content and nutritional offering were of less importance in the purchase decision of Cheddar cheese.

Both age groups indicated that flavour followed by price were significant ($p<0.05$) drivers influencing the purchase of Cheddar cheese (Table 10). Convenience played a role, but to a lesser degree than price. Consumers in the younger group were ambivalent towards packaging

and brand indicating that these two aspects played neither an important nor unimportant role in their buying decision. Fat content and nutritional offering were not considered important when purchasing Cheddar cheese. Results for the older group suggest that packaging, brand, fat content and nutritional offering did not play a significant role in the purchase decision of Cheddar cheese.

Table 8 Mean values for factors driving Cheddar cheese purchase intent with 1 = Not important and 9 = Extremely important.

Treatment	Cheese consumption
Flavour	8. 05 [a]
Price	7. 10 [b]
Convenience	6. 14 [c]
Packaging	5. 74 [cd]
Brand	5. 31 [de]
Fat	4. 87 [ef]
Nutrition	4. 80 [f]
LSD	**0. 50**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Table 9 Mean values for factors driving Cheddar cheese purchase intent by gender with 1 = Not important and 9 = Extremely important.

Treatment	Female consumers	Male consumers
Flavour	8. 04 [a]	8. 07 [a]
Price	7. 07 [bc]	7. 16 [b]
Convenience	6. 00 [de]	6. 37 [cd]
Packaging	5. 59 [ef]	5. 98 [de]
Brand	4. 93 [fg]	5. 93 [de]
Fat	4. 78 [g]	5. 02 [fg]
Nutrition	4. 36 [g]	5. 51 [ef]
LSD	**0. 73**	**0. 73**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Table 10 Mean values for factors driving Cheddar cheese purchase intent by age group with 1 = Not important and 9 = Extremely important.

Treatment	Age 19 - 24	Age 25 and older
Flavour	8. 16 [a]	7. 88 [ab]
Price	7. 21 [bc]	6. 92 [cd]
Convenience	6. 03 [ef]	6. 33 [de]
Packaging	5. 67 [efg]	5. 86 [ef]
Brand	5. 09 [ghi]	5. 69 [efg]
Fat	4. 61 [hi]	5. 32 [fgh]
Nutrition	4. 41 [i]	5. 45 [fg]
LSD	**0. 73**	**0. 73**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

3.6 Consumer hedonic responses to the colour of the six cheese treatments

ANOVA performed on the data tested the significance differences of the treatment means significance level of 95% ($p<0.05$). If the main effect was significant, a Least Significant Test (LSD) was performed to determine the direction of the differences between the treatments means. Mean scores for consumer liking of cheese colour are listed in Table 11. A significant difference in the colour liking was identified for the group as a whole and for female and male consumers individually.

For the total group of consumers Gouda received the highest score for colour liking at 7.76. This was followed by Cheddar at four months with a score of 7.31. Colour liking for Edam and Cheddar aged to 15 months was similar as there was no significant difference between the treatment means. The colour of these four cheeses was liked moderately by the consumer panel. Cheddar aged to 8 and 32 months received scores of 6.86 and 6.51, respectively, indicating that their colour was liked slightly and slightly less acceptable than the other four cheeses.

Colour liking scores for females followed the same trend with Gouda receiving the highest score of 7.87 with a significantly ($p<0.05$) higher level of liking than the other cheeses. This was followed by Cheddar at four months with a score of 7.32. Both cheeses were orange in colour. Edam and Cheddar aged to 15 months were also liked moderately, however, to significantly ($p<0.05$) lesser degree than the Gouda and Cheddar at 4 months. Colour liking for Cheddar cheeses at 8 and 32 months was less acceptable than the other four cheeses. These two cheeses were liked slightly by females.

Colour liking scores for the males differed only slightly from that of the female consumers. Colour liking for Gouda received the highest score of 7.59. This was followed by Edam and Cheddar at 4

months with scores of 7.27 and 7.29, respectively. Drake *et al.* (2008) found that both orange and white mild Cheddar coloured cheeses were appealing to consumers, although most consumers preferred mild Cheddar cheeses that were orange in colour.

These results indicate that male consumers liked coloured and uncoloured cheese equally while female respondents preferred a coloured cheese above an uncoloured cheese.

It is interesting to note that results in Chapter 4 reporting the instrumental colour analysis of the same six treatments of cheese, indicated that the Gouda and Cheddar at 15 months in age were not significantly different from one another. In other words, they received the same readings for luminosity, red hue and yellow shade, yet consumers indicated a definite preference for the Gouda colour. Results from the instrumental analysis also confirmed that Cheddar cheeses at 4, 8 and 32 months were not significantly different in colour from one another, yet consumers indicated different levels of liking. This would suggest that there are other factors that influence consumer perception and liking of cheese colour. For example the glossy surface, an attribute identified during DSA of the six cheese samples in Chapter 3, was higher in both the Gouda and Edam cheeses and lower but at the same level in the three older Cheddar cheese samples (Cheddar at 8, 15 and 32 months). The level of visible white crystals and moisture seepage, both descriptors identified during DSA (Chapter 3) may also have influenced consumer colour liking. Both attributes were only apparent in the three older Cheddar cheeses. In considering consumer liking of colour it would be prudent to consider the entire appearance of the cheese rather than colour alone.

Table 11 Mean values for colour liking of six cheese treatments with 1 = Dislike extremely and 9 = Like extremely.

Treatment	All consumers	Female consumers	Male consumers
Gouda	7. 76 [a]	7. 87 [a]	7. 59 [a]
Edam	7. 13 [b c]	7. 05 [b c]	7. 27 [a b]
Cheddar 4mo	7. 31 [b]	7. 32 [b]	7. 29 [a b]
Cheddar 8mo	6. 86 [c]	6. 74 [c d]	7. 06 [b c]
Cheddar 15mo	7. 02 [b c]	7. 00 [b c]	7. 06 [b c]
Cheddar 32mo	6. 51 [d]	6. 38 [d]	6. 72 [c]
LSD	**0. 29**	**0. 40**	**0. 44**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

3.6.1 Partial least-squares regression performed on consumer data for colour liking

Partial least-squares regression of the data for colour liking generated two components that summarised both the X and Y space adequately (Figure 1). Tenenhaus *et al.* (2005) suggest that in sensory analysis, two components are generally sufficient due to the low number of products. In this study, six samples of cheese were analysed.

The PLS plot in Figure 1 shows that consumers clearly preferred the colour of the Gouda and Cheddar aged to 4 months, and to a lesser extent Edam which was the only uncoloured cheese in this study. Results for the standardised coefficients of the descriptors (Figure 2) indicate that sour cream aroma, glossy appearance, sour taste, salty taste, creamy flavour, springiness, creaminess, instrumental colour attributes a*, b*, fat, moisture and salt content wielded the highest degree of influence over the dependent variable colour liking. This corresponds with the consumer acceptance results for colour liking (Table 11) and suggests that other aspects of cheese appearance such as glossy appearance influenced colour liking. As discussed previously; consumers preferred the Gouda colour over that of the Cheddar at 15 months maturity, yet instrumental analysis of cheese colour indicated that these two cheeses were the same colour. Consumers in this study also rejected the colour of the aged Cheddar cheeses at 8, 15 and 32 months. These cheeses were described by the trained sensory panel (Chapter 3) as having higher levels of visible white crystals and moisture seepage which may also have influenced consumer perception of colour.

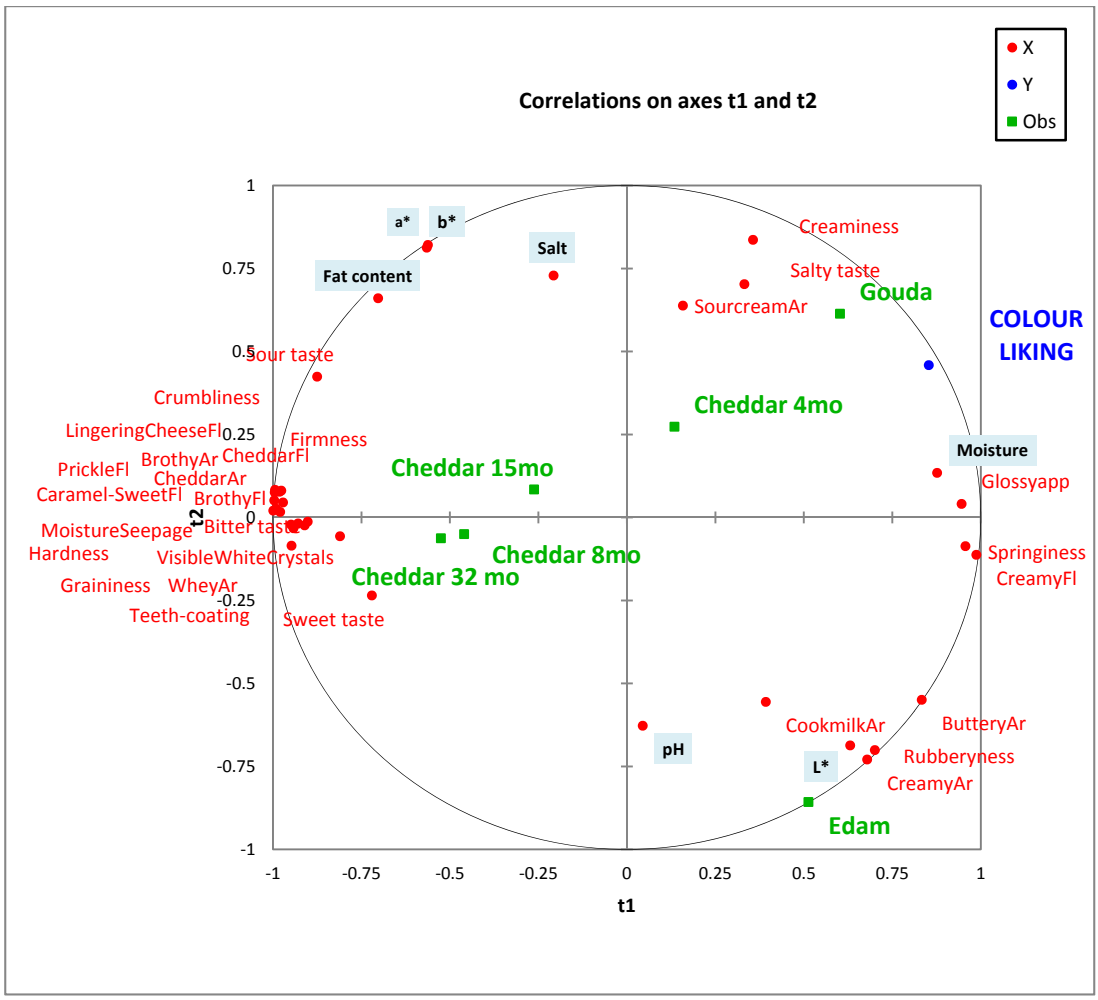

Figure 1 PLS plot indicating consumer acceptance of colour **(BLUE)** in relation to the six cheese treatments **(Green),** and selected sensory characteristics **(Red)** and instrumental attributes **(Black). "**Ar" and "Fl" represent aroma and flavour attributes, respectively.

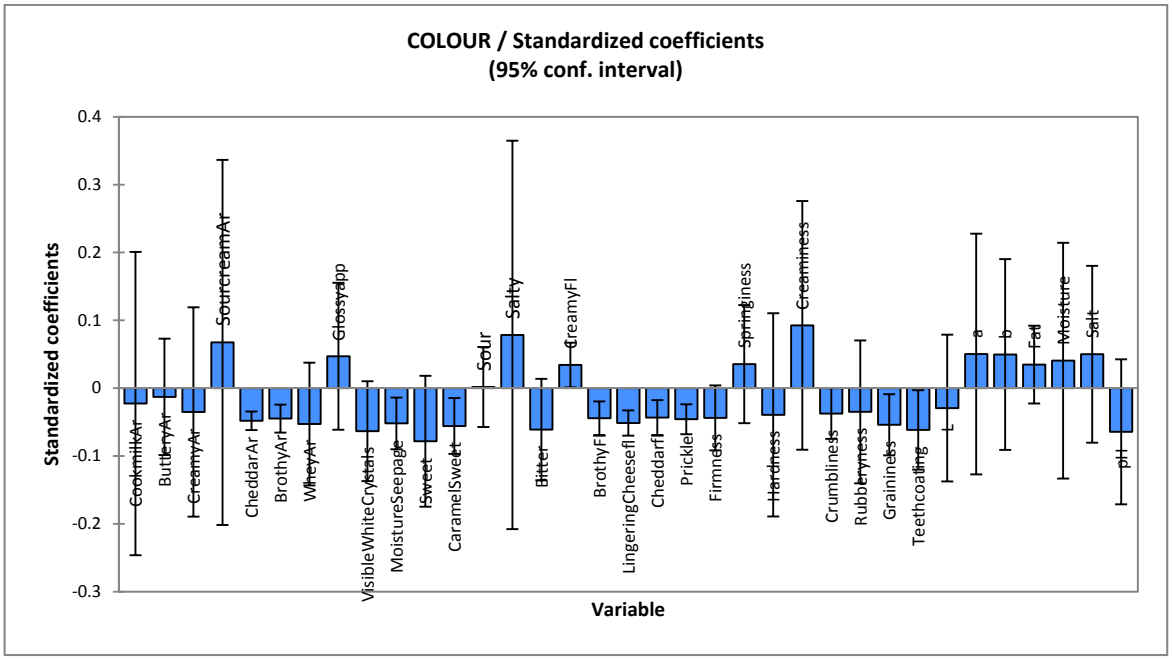

Figure 2 Standardised coefficients at a confidence interval of 95%, performed on consumer data for colour liking. Results indicate that the attributes sour cream aroma, glossy appearance, sour taste, salty taste, creamy flavour, springiness, creaminess, a*, b*, fat content, moisture content and salt content wielded the highest degree of influence over the dependent variable of Colour.

3.6.2 Hierarchical cluster analysis performed on the data for colour liking by consumers

Wards' clustering was performed on the consumer data for colour liking (Figure 3). Originally four clusters were formed, however, as the results for Cluster 1 and 3 were similar, both sets of data were combined into one cluster called Cluster 1 (Table 12).

ANOVA was performed for each one of the three clusters at a significance level of 95% (p = 0.05). If the main effect was significant, Fisher's test was performed to determine the direction of the differences between treatment means. Mean scores for colour liking within each cluster are listed in Table 13. A significant difference in colour liking was identified within each cluster.

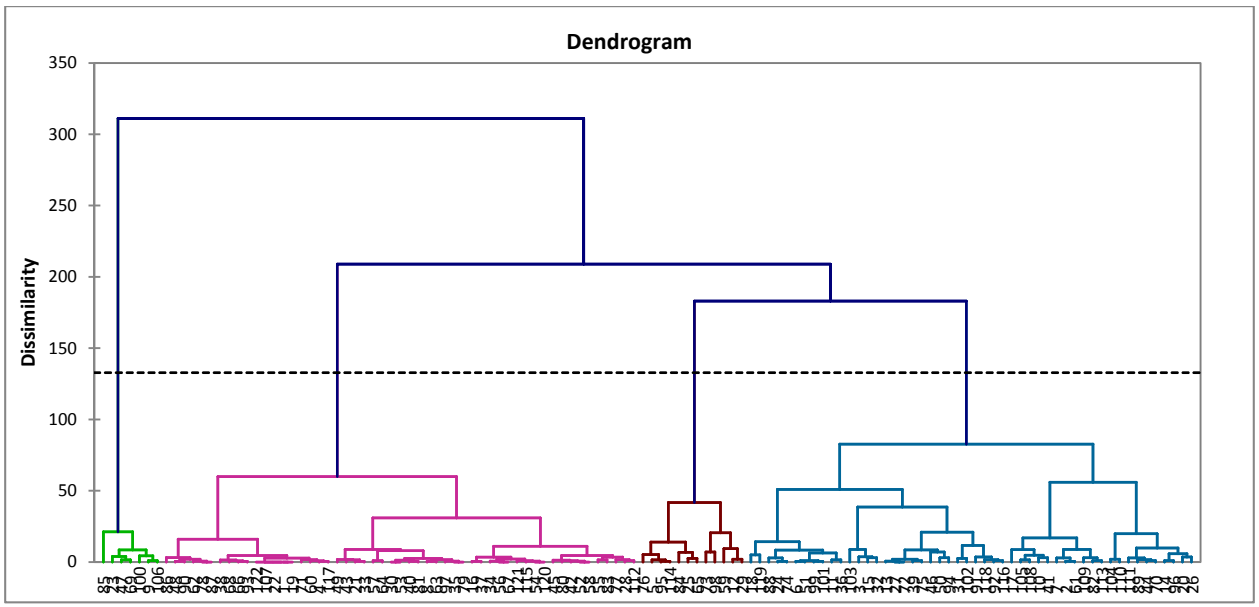

Figure 3 The dendogram of observations and sub-groups of the observations for the variable Colour of the consumer preference data. The dotted line represents the automatic truncation leading to three groups.

Table 12 Details outlining the classification of each cluster. Cluster 1 and Cluster 3 were combined due to their similar characteristics.

Class	1	2	3	4
Objects	53	50	12	7
Sum of weights	53	50	12	7
Within-class variance	3.636	9.107	10.098	6.714
Minimum distance to centroid	0.565	0.869	0.997	1.237
Average distance to centroid	1.775	2.838	2.850	2.209
Maximum distance to centroid	3.034	4.586	4.300	4.255

Table 13 Mean values for consumer colour liking of the six cheese treatments by cluster with 1 = Dislike extremely and 9 = Like extremely.

Treatment	Cluster 1	Cluster 2	Cluster 3
Gouda	7. 98 [a]	7. 80 [a]	5. 42 [b]
Edam	6. 66 [c]	7. 58 [a b]	7. 86 [a]
Cheddar 4mo	7. 74 [a b]	7. 26 [b c]	4. 29 [c]
Cheddar 8mo	7. 58 [b]	6. 40 [d]	4. 00 [c]
Cheddar 15mo	7. 58 [b]	6. 86 [c d]	3. 86 [c]
Cheddar 32mo	7. 55 [b]	5. 54 [e]	3. 71 [c]
LSD	**0. 31**	**0. 47**	**0. 99**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Respondents in Cluster 1 (Table 13) preferred the colour of the Gouda and Cheddar aged to 4 months and indicated that the colour was moderately liked. There was no significant difference for colour liking between the Cheddar cheeses aged to 8, 15 and 32 months and consumers indicated that these samples were also moderately liked, however, significantly ($p<0.05$) less than the Gouda and Cheddar at four months. The Edam, an uncoloured cheese, was liked slightly by this cluster.

Consumers in Cluster 2 (Table 13) also indicated a preference for Gouda, however, their hedonic score for “moderately liked” also included the Edam and Cheddar aged to 4 months, with little difference between the three cheeses for colour liking. The aged Cheddar cheeses were less liked by this cluster. The Cheddar cheeses aged to 8 and 15 months were liked slightly and the Cheddar aged to 32 months was liked significantly less.

Cluster 3 respondents significantly ($p<0.05$) preferred the colour of the Edam and indicated that the colour was moderately liked (Table 13). This was followed by the Gouda, however, Cluster 3 indicated that the colour was neither liked nor disliked. This cluster could not distinguish the colour between the remaining three Cheddar cheeses and indicated a slight to moderate dislike of the aged Cheese colour.

3.6.3 PLS regression performed on each cluster together with demographic data and consumer attitudes towards cheese

Partial least-squares regression was performed on each of the three clusters. Socio-demographic data and data generated from the consumer questionnaire were included in the analysis in an attempt to relate the variables. Cluster dummy variables were used as Y input for socio-demographic and attitudinal data. In some cases, the variables of age and consumption frequency were grouped together as there were too few observations. Unfortunately there was a poor prediction of the clusters from the socio-demographics; however, this is to be expected as the clusters were not well defined.

3.6.4 Composition of clusters for colour liking of the six cheese treatments

Cluster 1 Cluster 1 accounted for 53% of the participants in the consumer panel (Table 12). These consumers indicated a preference for the Gouda colour over that of the Cheddar cheeses, however, they could not differentiate between the Cheddar cheese colours. This group did not like the colour of the Edam cheese (Table 13).

The cluster was made up of males over the age of 25 who consumed cheese on a daily basis. They indicated a preference for extra mature Cheddar and mature Gouda. Cheese was consumed mainly as sandwich filler and on biscuits. These consumers indicated that price and packaging influenced their purchase decision (Figure 4).

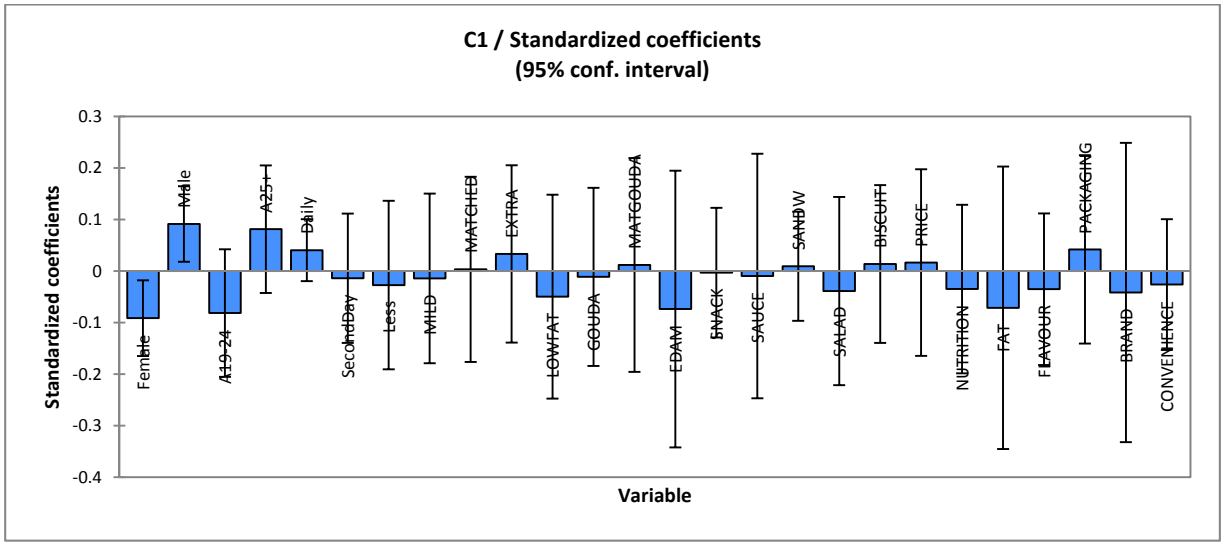

Figure 4 Standardised coefficients for Cluster 1 based on colour preference. Results indicate that male, 25+, daily consumption, mature Cheddar, extra mature Cheddar, mature Gouda, sandwich, biscuit, price and packaging significantly influenced the dependent C1 variable.

Cluster 2 This cluster comprised 41% of the consumer preference for colour liking (Table 12). Consumers in this cluster liked Gouda and Edam colour equally. However, consumers in this cluster could not clearly distinguish between the Cheddar cheeses and they did not like the colour of the 32 month old Cheddar (Table 13).

The cluster was made up of females between the ages of 19 and 24 who consumed cheese every second day. These consumers indicated a preference for low fat, Edam and Gouda cheeses. Convenience, fat content and nutritional offering influenced their buying decision and in most cases, cheese was consumed in a sauce (Figure 5).

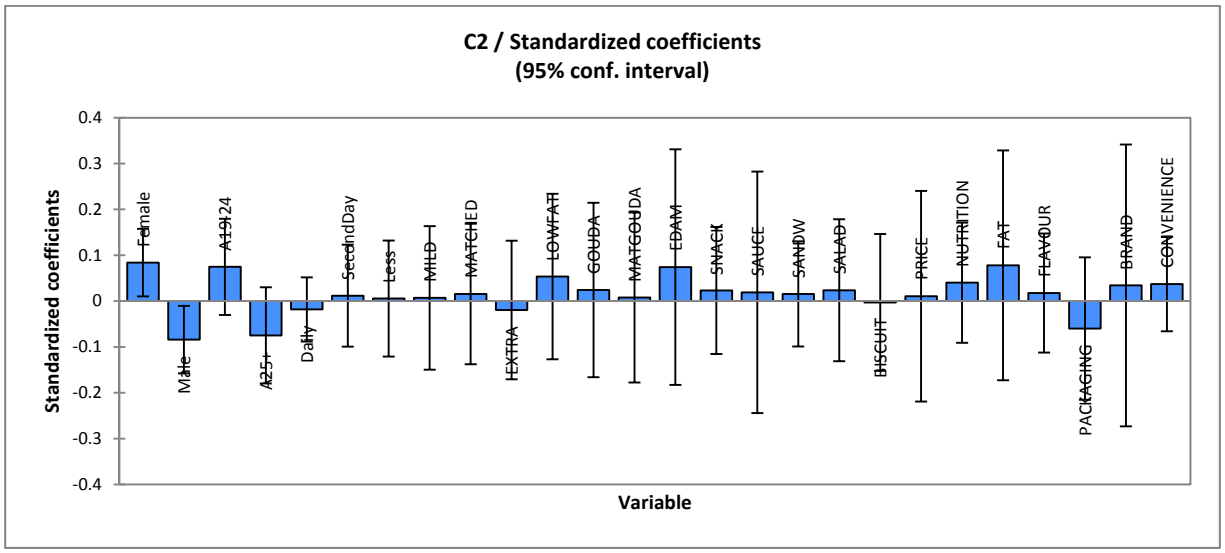

Figure 5 Standardised coefficients for Cluster 2 based on colour preference. Results indicate that the variables female, 19 – 24, second day, less, mature Cheddar, low fat, Gouda, mature Gouda, Edam, snack, sauce, sandwich, price, nutrition, fat content, flavour, brand and convenience significantly influenced the dependent variable C2.

Cluster 3 Cluster 3 comprised 7% of the participants in the consumer panel (Table 12). These consumers preferred the Edam colour significantly more than the Gouda colour and the Gouda colour significantly more than the Cheddar cheese colour. This cluster of consumers, however, could not distinguish between the Cheddar cheese colours (Table 13).

This group consisted of females between the ages of 19 and 24 who consumed cheese on a less frequent basis. They indicated a preference for mild Cheddar cheese. Generally they consumed cheese in a salad and identified flavour, packaging and brand as playing a role in their buying decision (Figure 6).

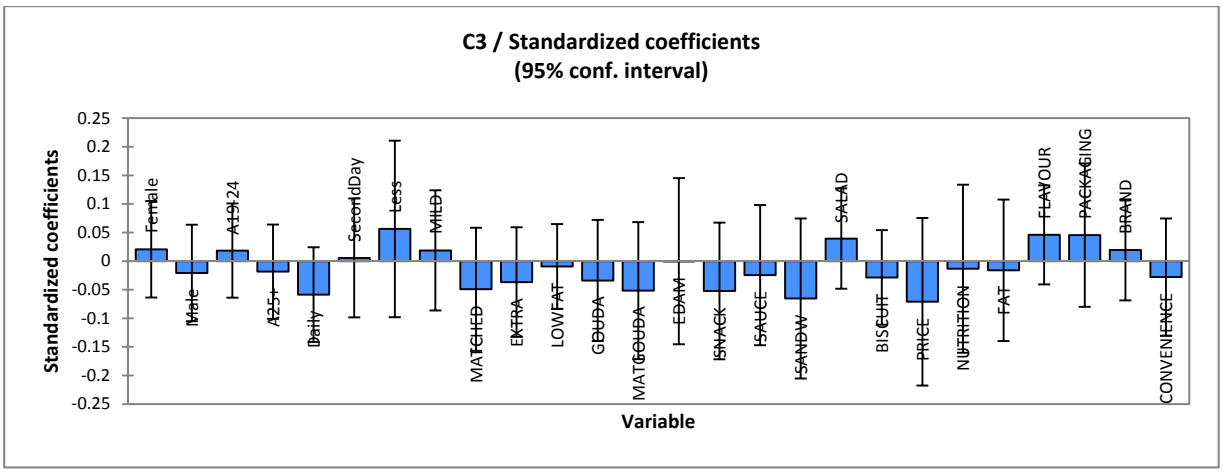

Figure 6 Standardised coefficients for Cluster 3 based on colour preference. Results indicated that variables female, 19 -24, second day, less frequent consumption, mild Cheddar cheese, salad, flavour, packaging and brand significantly influenced the dependent variable of C3.

3.6.5 Product optimisation per cluster

Based on the PLS performed on the hedonic data for colour liking and the subsequent cluster analysis (Figures 7, 8 and 9), product optimisation per cluster is detailed below and summarised in Table 14.

Optimised cheese colour for Cluster 1 A coloured cheese would be preferred by this cluster and an uncoloured cheese would be rejected. Since the Gouda and Cheddar aged to 15 months received the same readings for instrumental analysis, it would seem that the attribute glossy played a role in colour preference for this cluster. Therefore an orange coloured cheese with a glossy appearance would be an optimised colour solution for males over the age of 25 who consume cheese on a daily basis. Furthermore, a coloured cheese satisfies the indicated preference for this cluster as mature, extra mature, Gouda and mature Gouda cheeses are generally orange in colour. As a key driver for purchase, packaging would have to be attractive to the consumer as too would the price of the cheese.

Optimised cheese colour for Cluster 2 Both coloured and uncoloured cheeses would appeal to this cluster. Any cheese characterised as having a dull colour, with visible white crystals and moisture seepage would be rejected. These characteristics are commonly found in aged cheeses. Therefore, female consumers between the ages of 19 and 24 who eat cheese every second day would find either coloured or uncoloured cheese with a slight glossy appearance to be an optimised product. Furthermore, the uncoloured cheeses would suit this cluster as indicated preference was for low fat, Edam and Gouda cheese. Low fat and Edam cheeses are generally uncoloured. To increase consumption, the cheese would primarily have to satisfy fat content concerns and emphasise the nutritional benefits that cheese can offer. Convenience would also play a role.

Optimised cheese colour for Cluster 3 An uncoloured cheese would appeal to this cluster. Uncoloured cheeses characterised as glossy would be preferred above those characterised as having a dull appearance with visible white crystals and moisture seepage by females aged between 19 and 24. Focus should be on mild Cheddar type cheeses as this is indicated as their preferred cheese choice. Since this cluster only consumes cheese once or twice per week, increased consumption should be achieved through promotion of cheese as a sandwich filler and a snack rather than just as a salad ingredient. Furthermore, consumption could be increased by emphasising the flavour characteristics of the cheese and satisfying packaging requirements for this cluster. It is interesting to note that of the three clusters identified, Cluster 3 was the only group that indicated brand as one of the key drivers in cheese purchase decisions.

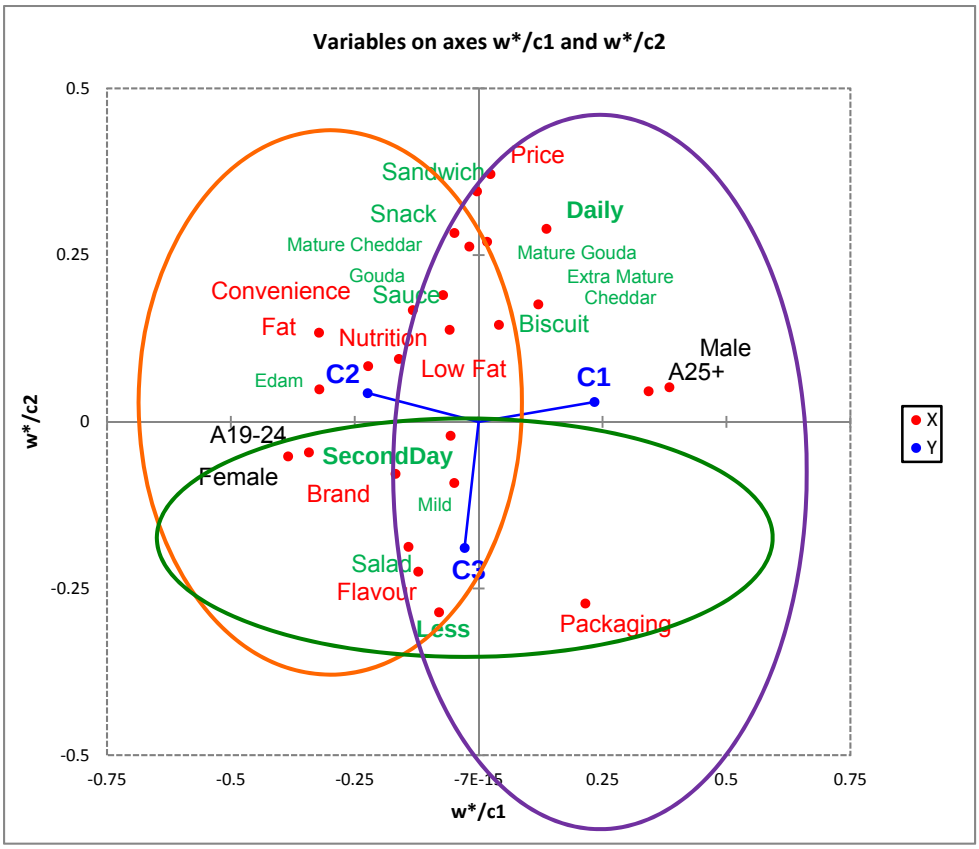

Figure 7 PLS plot illustrating the relationship between consumer preference for colour **(Clusters 1, 2 and 3)**, socio-demographic data **(Black)**, consumption data **(Green)** and factors influencing purchase intent **(Red)**.

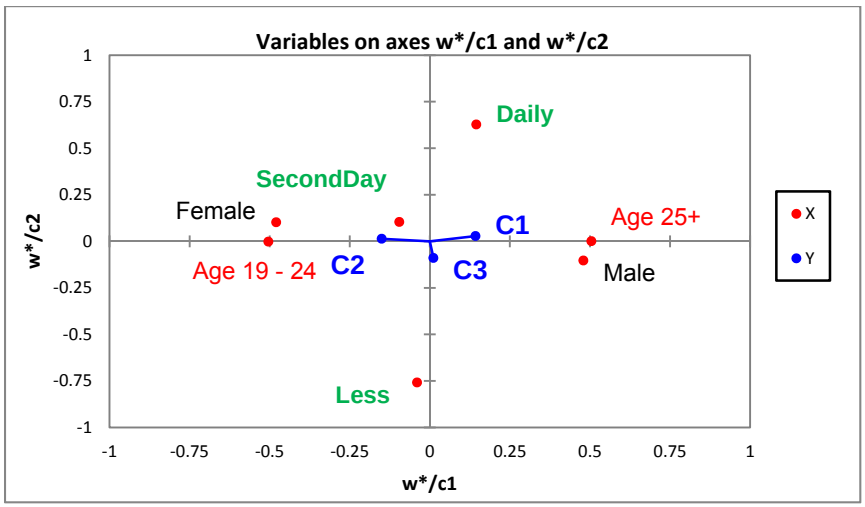

Figure 8 PLS plot illustrating the relationship between each cluster **(C1, C2 and C3)** for colour liking, gender **(Black),** age **(Red)** and frequency of consumption **(Green)**.

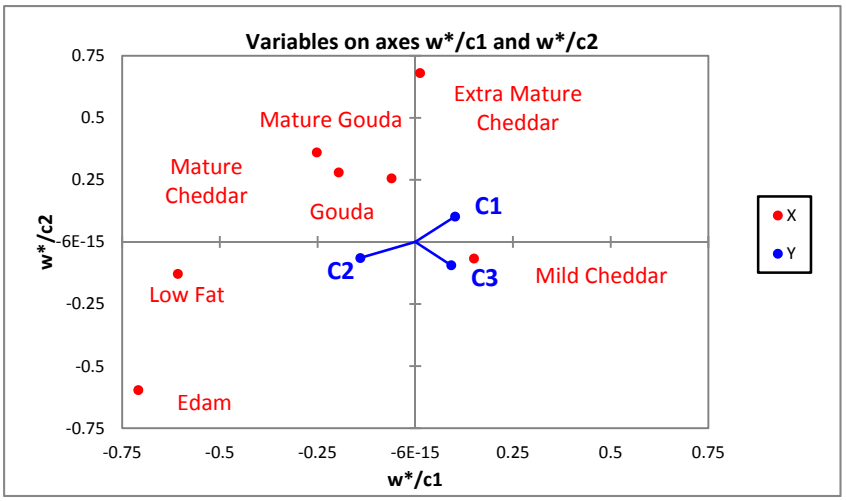

Figure 9 PLS plot showing the relationship between each cluster **(C1, C2 and C3)** for colour liking of the cheese and indicated preference for cheese type **(Red)**.

Table 14 Summary of the features characterising each cluster based on hedonic scores for colour liking.

	Cluster 1	Cluster 2	Cluster 3
Cheese preference identified from hedonic scores in consumer analysis.	Preferred the colour of the Gouda cheeses above the mature Cheddar cheeses. Did not like the Edam colour.	Liked the colour of the Gouda and Edam chesses equally. Could not distinguish between the Cheddar cheese colours. Did not like the colour of the 32mo Cheddar cheese.	Preferred the Edam cheese colour significantly ($p<0.05$) more than the Gouda colour and the Gouda colour significantly ($p<0.05$) more than the Cheddar cheese colour, although could not distinguish between the Cheddar cheese colours.
Size of Cluster	53% of total consumer panel.	41% of total consumer panel.	6% of total consumer panel.
Gender composition	Male	Female	Female
Age	25 years and older	19 – 24 years	19 – 24 years
Consumption of cheese	Daily	Every second day	Once or twice a week.
Indicated preference for cheese	Extra mature Cheddar, Gouda, mature Gouda and mature Cheddar.	Low fat, Edam and Gouda cheese.	Mild Cheddar.
Way in which cheese consumed	Cheese on biscuits, as a snack and as a sandwich-filler.	As a sauce ingredient.	As a salad ingredient.
Factors influencing purchase intent	Price.	Convenience, fat content and nutritional offering.	Flavour and packaging and brand.

3.7 Consumer hedonic responses to the texture characteristics of the six cheese treatments

Results of the consumer acceptance testing of texture liking for the six cheese treatments are discussed in the paragraphs below. ANOVA was performed to determine whether there was a significant difference between treatment means at a significance level of 95% ($p<0.05$). If the main effect was significant, Fisher's test was performed to determine the direction of the differences between treatment means. Mean scores for consumer liking of cheese texture are listed in Table 15. A significant difference ($p<0.05$) in texture liking was identified for the group as a whole and for female and male consumers individually.

Table 15 Mean values for consumer texture liking of the six cheese treatments with 1 = Dislike extremely and 9 = Like extremely.

TREATMENT	All consumers	Female consumers	Male consumers
Gouda	7. 26 [a]	7. 35 [a]	7. 11 [b a]
Edam	7. 55 [a]	7. 59 [a]	7. 50 [a]
Cheddar 4mo	7. 37 [a]	7. 23 [a]	7. 59 [a]
Cheddar 8mo	5. 81 [b]	5. 47 [b]	6. 36 [c]
Cheddar 15mo	6. 07 [b]	5. 76 [b]	6. 59 [b c]
Cheddar 32mo	4. 96 [c]	4. 56 [c]	5. 61 [d]
LSD	**0. 39**	**0. 50**	**0. 62**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Edam received the highest score for texture liking; however, this result was not significantly different from Gouda and Cheddar aged to 4 months ($p>0.05$). The texture for Gouda, Edam and Cheddar at four months was equally liked. Cheddar cheeses at 8 and 15 months were not significantly different and were neither liked nor disliked by consumers. Cheddar aged to 32 months received the lowest score and was disliked slightly.

The sensory texture of the Edam was characterized as springy, firm and creamy with a degree of rubbery texture (Chapter 3). Gouda was described as springy, creamy and firm while Cheddar at 4 months was characterised as being predominantly firm, creamy and hard. This cheese was, however, less springy and slightly crumblier than the Gouda and Edam. The texture of Cheddar cheeses at 8, 15 and 32 months, respectively was predominantly characterized by firmness, creaminess and hardness. The cheeses were also crumbly and grainy with aspects of teeth-coating. Cheddar aged to 32 months and disliked slightly by consumers, was the grainiest cheese with the highest level of teeth-coating.

Female acceptance followed a similar trend with Edam and Cheddar at 32 months receiving the highest and lowest scores, respectively for texture liking. Gouda, Edam and Cheddar at 4 months were all equally liked. Cheddars at 8 and 15 months were neither liked nor disliked.

Male and female liking of cheese texture was similar; however, female respondents preferred the texture of the three younger cheeses while the male consumers preferred the Edam and 4 month old Cheddar cheese. The oldest cheese, the Cheddar at 32 months received the lowest score for liking by both male and female respondents, however, the male consumers tended to rate the cheese slightly higher than the female consumers. Females therefore preferred the texture of the younger cheeses, described as springy, firm and creamy, while men preferred slightly older cheeses described as springy, firm, creamy and slightly crumbly. Neither group liked the texture of the older cheeses described as firm, creamy and hard, slightly grainy and crumbly with a low level of teeth-coating (See Chapter 3 for textural qualities).

3.7.1 Partial least-squares regression performed on consumer data for texture liking

Partial least-squares regression of the data for texture liking generated two components that summarised both the X and Y space adequately. The PLS plot (Figure 10) also shows that consumers preferred the texture of the Cheddar cheese aged to 4 months, the Gouda and the Edam cheeses. Standardised coefficient results (Figure 11) suggest that the attributes cooked milk aroma, buttery aroma, creamy aroma, glossy appearance, sour taste, creamy flavour, springiness, hardness, instrumental a*, b* values, as well fat and salt content had the greatest effect on the dependent texture variable. These attributes generally describe flavours identified in young cheeses (Drake *et al.*, 2001). The standardised coefficient results for texture indicated that springiness and hardness were the two textural attributes that significantly ($p<0.05$) influenced consumer texture liking.

Investigation of the correlation matrix further explains the influence of textural properties on consumer liking. Negative correlations were identified between texture liking and graininess ($r = -0.971$), crumbliness ($r = -0.885$), teeth-coating ($r = -0.959$) and firmness ($r = -0.850$), suggesting that consumers in this study did not like the textural attributes identified in the aged Cheddar cheeses. Springiness, is the one attribute that positively influenced consumer liking of texture ($r = 0.785$). Although springiness characterised the texture of the Gouda, Edam and Cheddar aged to 4 months at significantly different levels, it was not identified in the aged Cheddar cheeses at any significant level (Chapter 3). It can be concluded then that consumers in this study preferred the cheeses characterised by a springy texture and rejected those cheeses characterised by high levels of graininess, crumbliness, teeth-coating and firmness.

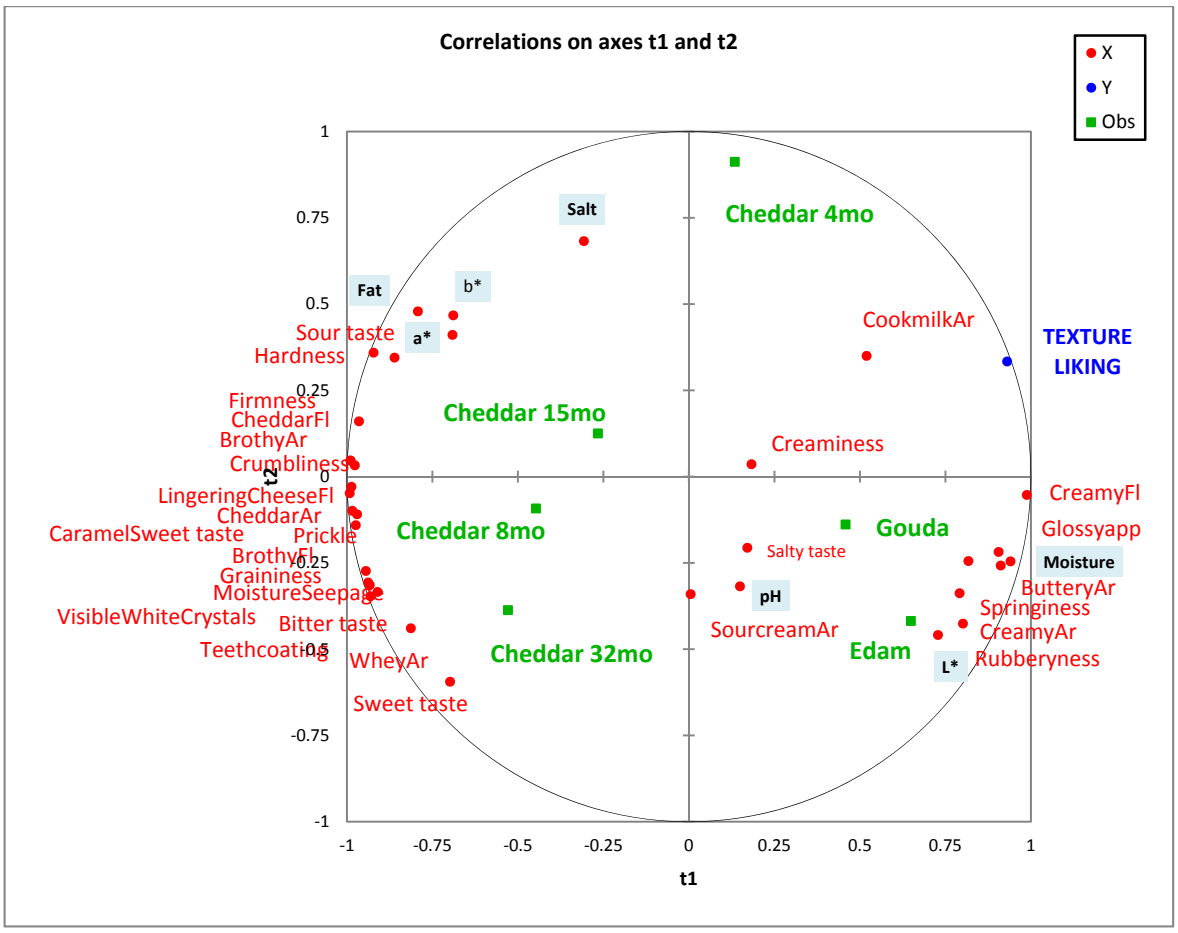

Figure 10 PLS plot indicating consumer acceptance of texture **(BLUE)** in relation to the six cheese treatments **(Green),** and selected sensory characteristics **(Red)** and instrumental attributes **(Black). "**Ar" and "Fl" represent aroma and flavour attributes, respectively.

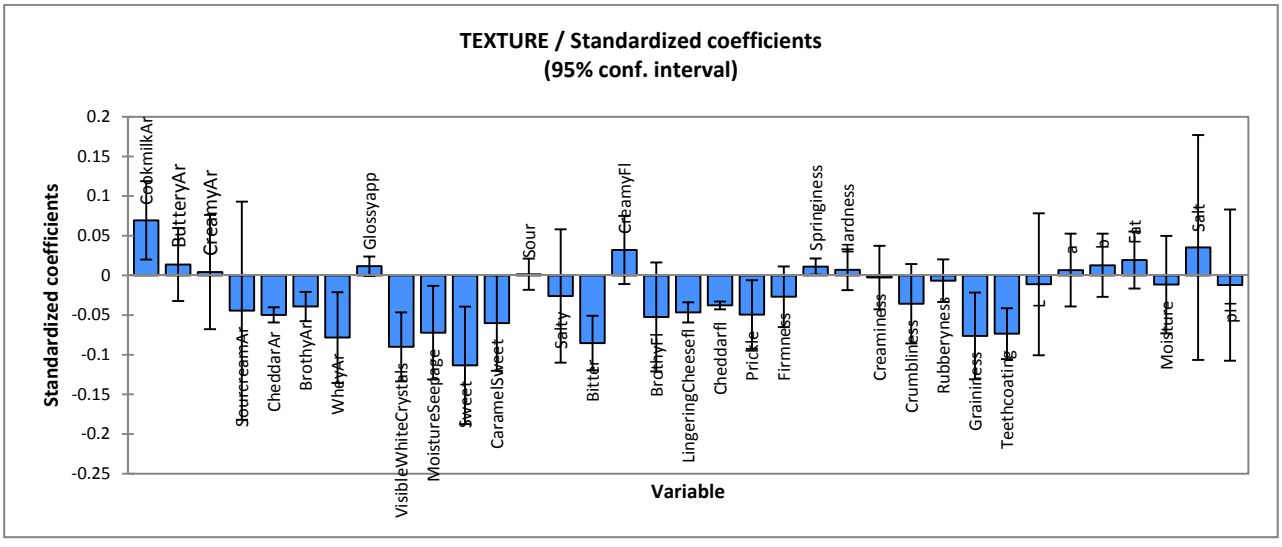

Figure 11 Standardised coefficients at a confidence interval of 95% performed on the consumer data for texture liking. Results indicated that cooked milk, buttery and creamy aroma, glossy appearance, sour taste, creamy flavour, springiness, hardness, a*, b*, fat content and salt content significantly influenced the dependent variable Texture.

3.7.2 Hierarchical cluster analysis performed on the data for Texture liking of the six cheese treatments

Wards cluster analysis was performed on the consumer preference data (Figure 12). Three clusters were derived from the analysis for the variable texture. The main objective of this procedure was to find similarities between the consumers based on their texture preferences. The similarities were then grouped together to assist in understanding any relationships that may have existed between the consumers.

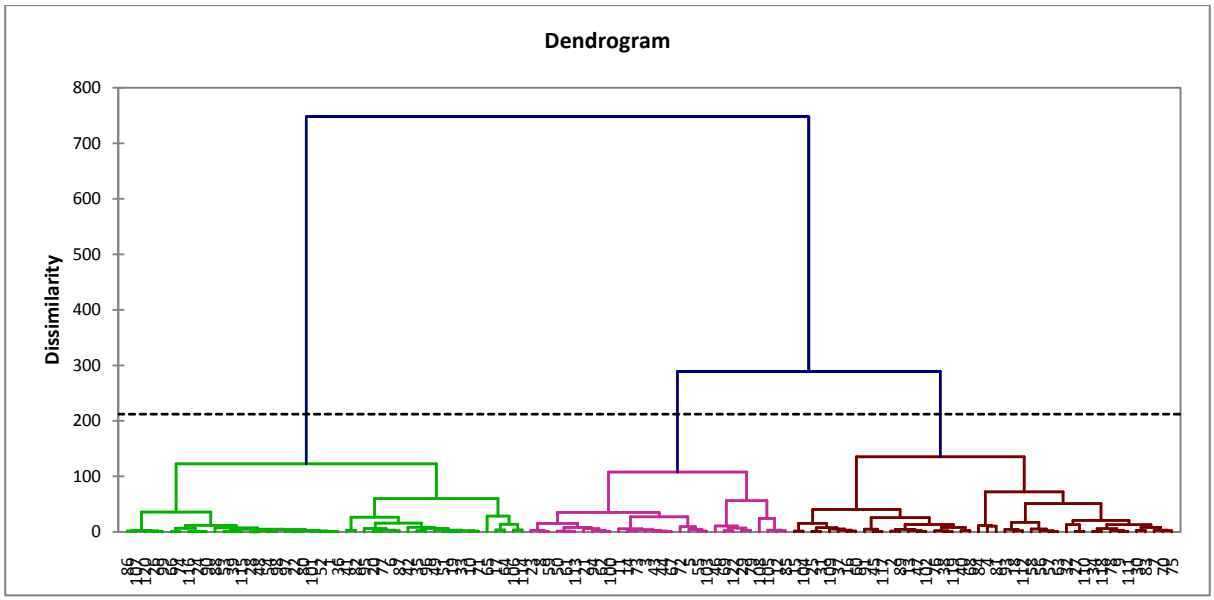

Figure 12 The dendogram of observations and sub-groups of the observations for the variable texture of the consumer preference data. The dotted line represents the automatic truncation leading to three groups.

Table 16 Details outlining the classification of each cluster based on consumer texture preference scores.

Class	1	2	3
Objects	46	44	30
Sum of weights	46	44	30
Within-class variance	9.020	12.357	12.055
Minimum distance to centroid	0.822	1.474	1.322
Average distance to centroid	2.679	3.283	3.149
Maximum distance to centroid	6.408	6.328	7.551

ANOVA was performed at a significance level of 95% (p = 0.05) for each of the three clusters. If the main effect was significant, Fisher's test was performed to determine the direction of the

differences between the mean values. Mean scores for texture liking within each cluster are listed in Table 17. Significant differences in texture liking were identified within each cluster.

Table 17 Mean values for texture liking of the six cheese treatments by cluster with 1 = Dislike extremely and 9 = Like extremely.

Treatment	Cluster 1	Cluster 2	Cluster 3
Gouda	7. 50 [a b]	6. 83 [b]	7. 84 [a]
Edam	7. 38 [a b]	7. 51 [a]	7. 68 [a]
Cheddar 4mo	7. 77 [a]	7. 10 [a b]	7. 56 [a]
Cheddar 8mo	7. 44 [a b]	5. 45 [c]	3. 68 [b]
Cheddar 15mo	7. 34 [a b]	5. 97 [c]	3. 79 [b]
Cheddar 32mo	7. 10 [b]	4. 32 [d]	2. 84 [c]
LSD	**0. 53**	**0. 56**	**0. 65**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

Respondents in Cluster 1 could not seem to distinguish wholly between the six cheese samples. Cheddar aged to 4 months received the highest score for texture liking, however, this was not significantly different from the Gouda, Edam and the two Cheddar cheeses aged to 8 and 15 months respectively. All five samples were moderately liked. Cheddar aged to 32 months received a significantly ($p<0.05$) lower score than the other cheeses. It nevertheless was also moderately liked by this cluster (Table 17).

Consumers in Cluster 2 preferred the texture of the Edam and the Cheddar aged to 4 months. Both cheeses were scored as moderately liked. Gouda followed with a significantly lower score for texture. Consumers could not differentiate between the Cheddar cheeses aged to 8 and 15 months and rated both as neither liked nor disliked. Cheddar aged to 32 months received the lowest score indicating that it was disliked slightly (Table 17).

Cluster 3 respondents indicated a moderate liking for the texture of the Gouda, Edam and Cheddar aged to 4 months. Hedonic scores for texture liking of these three cheeses were significantly ($p<0.05$) higher than that of the remaining cheeses. The two Cheddar cheeses aged to eight and 15 months were moderately disliked and the texture of the Cheddar aged to 32 months was disliked very much (Table 17).

3.7.3 PLS regression performed on each cluster together with demographic data and consumer attitudes towards cheese

Partial least-squares regression was performed on each of the three clusters. Demographic data and data generated from the consumer questionnaire were included in the analysis in an attempt to relate the variables. Cluster dummy variables were used as Y input for socio-demographic and attitudinal data. In some cases the variables of age and consumption frequency were grouped together as there were too few observations. Unfortunately there was a poor prediction of the clusters from the demographics; however, this is to be expected as the clusters were not well defined.

3.7.4 Composition of Clusters for texture liking of the six cheese treatments

Cluster 1 Cluster 1 comprised 38% of the consumer respondents (Table 16). These consumers could not distinguish between the textures of the six cheese samples, however, indicated a moderate liking for the texture of all six samples (Table 17). This cluster was made up of males over the age of 25 who consumed cheese on a daily basis. These respondents indicated a preference for mild, mature and extra mature Cheddar, mature Gouda and Edam. Consumption of cheese was as a snack, in a sauce, on biscuits and as a sandwich filling. Price, nutritional content and fat content contributed to their cheese buying decision; however, brand and convenience played a much larger role (Figure 13).

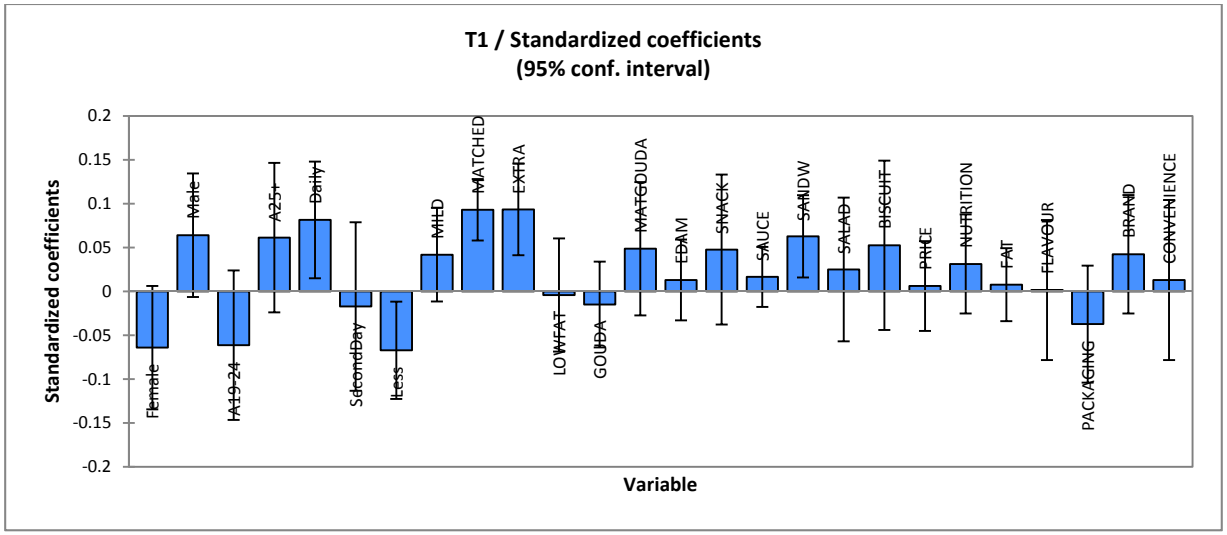

Figure 13 Standardised coefficient results for Cluster 1 based on texture preference. Results indicate that male, age 25+, daily consumption, mild, mature and extra mature Cheddar, mature Gouda, Edam, snack, sandwich, salad, biscuit, price, nutrition, fat content, flavour, brand and convenience significantly influenced the dependent variable of Texture.

Cluster 2 Cluster 2 comprised 37% of the consumer panel (Table 16). These consumers, males over the age of 25, preferred the texture of the Edam and the Cheddar cheese aged to four months above the Gouda cheese. The Cheddar cheeses aged to 8 and 15 months were neither liked nor disliked and the Cheddar at 32 months was disliked slightly (Table 17). Respondents in this cluster consumed cheese every second day and indicated a preference for Edam, low fat and mild Cheddar cheese. Cheese was generally consumed in a sauce or salad. Price, fat content and nutritional offering influenced purchase decisions regarding cheese (Figure 14).

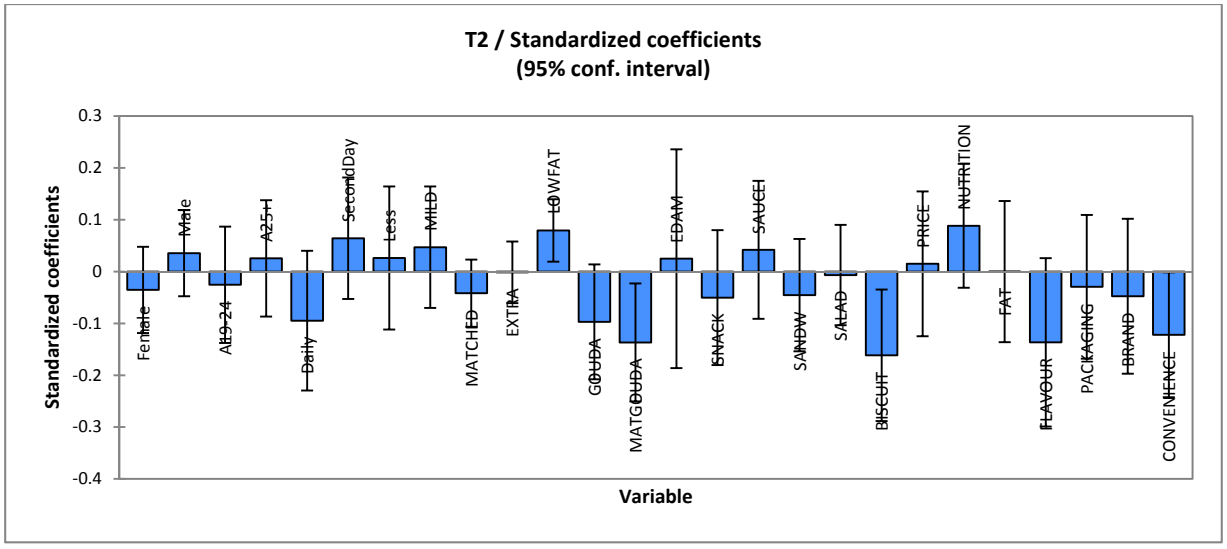

Figure 14 Standardized coefficients for Cluster 2 based on texture preference. Results indicate that male, age 25+, second day consumption, less frequent consumption, mild Cheddar, low fat cheese, Edam, sauce, price and nutritional offering significantly influenced the dependent variable of Texture.

Cluster 3 Respondents in Cluster 3 comprised 25% of the consumer panel (Table 16). This groups was made up of females between the ages of 19 and 24. These consumers preferred the texture of the Gouda, Edam and Cheddar aged to 4 months. Texture of the Cheddar cheeses aged to 8 and 15 months was moderately disliked and the texture of the Cheddar at 32 months was disliked very much (Table 17). The group indicated a preference for Gouda cheese and consumed cheese infrequently. Flavour, convenience and packaging influenced cheese purchase decisions (Figure 15).

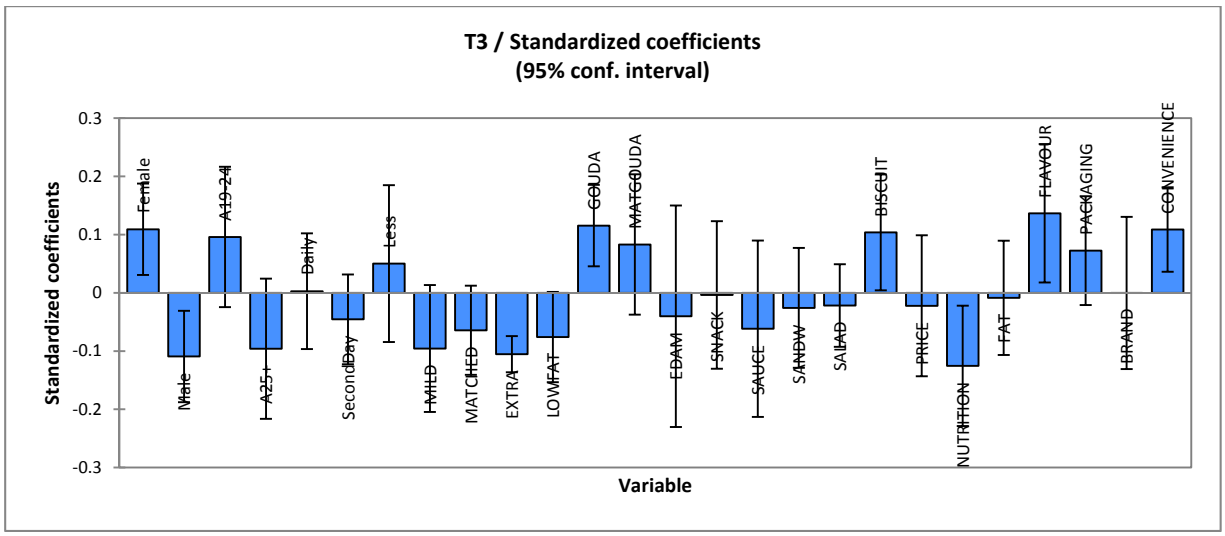

Figure 15 Standardised coefficients for Cluster 3 based on texture preference. Results indicated that female, age 19 – 24, daily consumption, less frequent consumption, Gouda, mature Gouda, biscuit, flavour, packaging and convenience significantly influenced the dependent variable of Texture.

3.7.5 Product optimisation per cluster

Based on the PLS regression analyses performed on the hedonic data for texture liking and the subsequent cluster analysis, product optimisation per cluster is detailed below (Figures 16, 17 and 18). Also refer to Table 18 for a summary of factors affecting liking of texture of the three clusters.

Optimised Texture for Cluster 1 Cheeses characterised by textural attributes of creamy, springy and rubbery are optimised for male consumers over the age of 25 who eat cheese every day. These attributes are generally associated with the textural development of young cheeses. Although this cluster indicated a preference for mature and extra mature Cheddar cheese, textural attributes of firmness, graininess, hardness and teeth-coating, predominantly found in aged Cheddar cheese, would not be well accepted. Additional consumption could be encouraged through branding as these consumers are influenced primarily by brand. Furthermore, promotion of the products nutritional offering and fat content may also influence purchase behaviour.

Optimised texture for Cluster 2 Two types of cheese texture would appeal to this cluster. Cheeses predominantly characterised by a rubbery texture, springiness and creaminess together with cheeses described as creamy with slight rubbery and springy characteristics would be optimised for male consumers over the age of 25. To encourage consumption, as this cluster eats cheese only every second day and mainly as a sauce ingredient, focus should be on cheese as a nutritional food ideal for salads and as a snack. Furthermore, price plays a key role in decision making. Concepts promoting cheese as good value for money should therefore be considered. Flavour, convenience, packaging and brand will not influence purchase behaviour.

Optimised texture for Cluster 3 Cheese textures described as rubbery, springy and creamy would be optimised for female consumers between the ages of 19 and 24. These attributes are generally found in younger cheeses which would suit this group as their indicated preference is for Gouda-type cheeses. This cluster would emphatically reject a cheese described as hard, crumbly and grainy. As this cluster consumes cheese infrequently, focus should be on the distinct flavour offering by the cheese and its suitability as sandwich filler, a salad ingredient and as a snack, and not just on biscuits. Packaging and convenience will also influence positive cheese consumption.

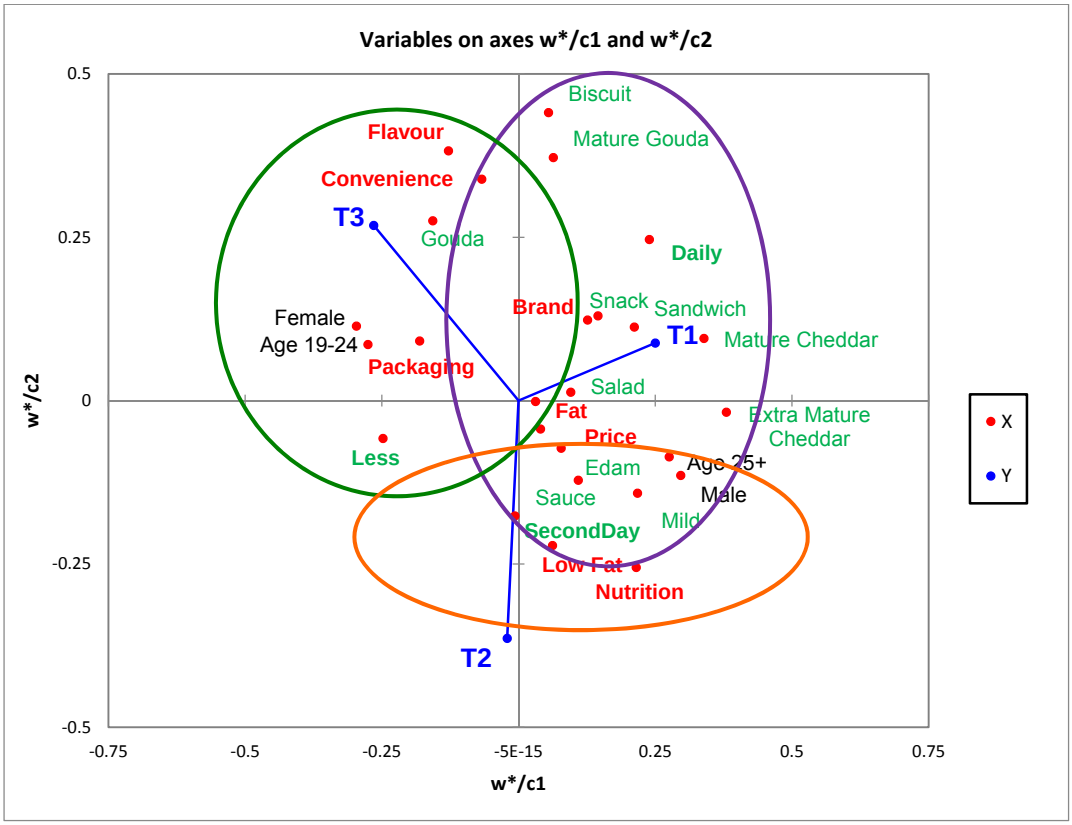

Figure 16 PLS plot showing the relationship between each cluster based on texture preference. The map includes socio-demographic data **(Black)**, consumption data **(Green)** and factors influencing purchase intent **(Red)**.

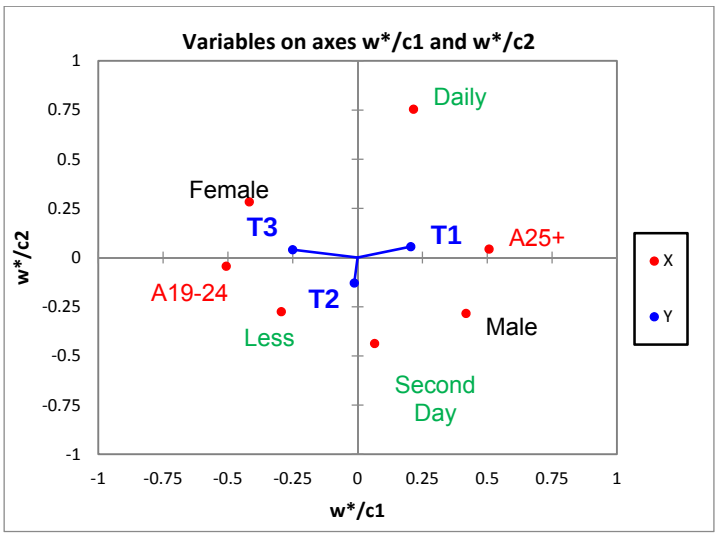

Figure 17 PLS plot visualising the relationship between each cluster **(T1, T2 and T3)** for texture liking, gender **(Black)**, age **(Red)** and frequency of consumption **(Green)**.

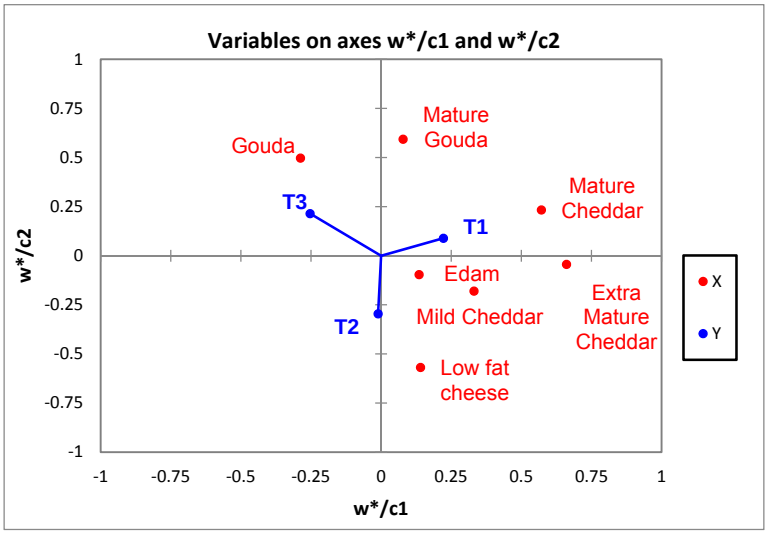

Figure 18 PLS plot visualising the relationship between each cluster **(T1, T2 and T3)** for texture liking of the cheese and indicated preference for cheese type **(Red)**.

Table 18 Summary of the features characterising each cluster based on hedonic scores for texture liking.

	Cluster 1	Cluster 2	Cluster 3
Cheese preference identified from hedonic scores in consumer analysis.	Could not distinguish between the textures of the six samples. All were moderately liked; however, Cheddar matured to 32 months was less appreciated.	Preferred the texture of the Edam and Cheddar aged to four months. Did not like the texture of the 32 month mature Cheddar cheese.	Preferred the Gouda, Edam and Cheddar cheese matured to four months above the texture of the older Cheddar cheese samples.
Sensory description of the cheese texture	Cheddar at 32 months predominantly characterised by attributes of firmness, graininess, hardness, crumbliness and teethcoating.	Edam cheese characterised by springiness and rubberyness. Cheddar at four months characterised by creaminess. Cheddar at 32 months described by high levels of graininess and teeth-coating.	Gouda, Edam and Cheddar cheese textures described by creaminess, rubberyness, springiness and firmness. The aged Cheddar cheeses were characterised by hardness, crumbliness, graininess and teethcoating.
Size of Cluster	38% of respondents	37% of respondents	25% of respondents
Gender composition	Male	Male	Female
Age	25 years and older	25 years and older	19 – 24 years
Consumption of cheese	Daily	Every second day	Infrequently – once or twice a week
Indicated preference for cheese	Mild, mature and extra mature Cheddar, mature Gouda and Edam	Mild, low fat and Edam cheese	Gouda and mature Gouda
Way in which cheese consumed	Snack, sauce, sandwich filler, salad and on biscuits	Sauce	On biscuits
Factors influencing purchase intent	Price, nutritional and fat content, flavour, brand and convenience	Price and nutritional content	Flavour, packaging and convenience

3.8 Consumer hedonic responses to the flavour characteristics of the six cheese treatments

ANOVA was performed to ascertain significant differences between treatment means at a significance level of 95% ($p< 0.05$). If the main effect was significant, Fisher's test was performed to determine the direction of the differences between the mean values. Mean scores for consumer liking of cheese flavour are listed in Table 19. A significant ($p<0.05$) difference in the flavour liking was identified for the group as a whole, as well as for female and male consumers.

Table 19 Mean values for consumer flavour liking of the six cheese treatments with 1 = Dislike extremely and 9 = Like extremely.

Treatment	All consumers	Female consumers	Male consumers
Gouda	6. 99 [a]	6. 91 [a]	7. 11 [a]
Edam	7. 27 [a]	7. 26 [a]	7. 29 [a]
Cheddar 4mo	7. 14 [a]	7. 08 [a]	7. 25 [a]
Cheddar 8mo	5. 56 [c]	5. 26 [c]	6. 04 [b]
Cheddar 15mo	6. 48 [b]	6. 28 [b]	6. 81 [a]
Cheddar 32mo	5. 06 [d]	4. 73 [c]	5. 61 [b]
LSD	**0. 46**	**0. 60**	**0. 72**

[1]Least Significant Difference ($p = 0.05$)

[2] Values with the same superscript are not significantly different

According to Table 19 Edam received the highest score of 7.27 for flavour liking; however, this was not significantly different from either the Gouda or the Cheddar aged to 4 months. Consumers were able to identify a difference between Cheddars at 8, 15 and 32 months regarding flavour development and seemed to prefer the younger cheese flavours more than the older cheese flavours. Cheddar aged to 15 months, characterised by young flavours was favoured above Cheddar at 8 months maturity, characterised by higher levels of aged flavours. The oldest Cheddar, aged to 32 months was the least liked cheese.

Female respondents allocated the highest score of 7.26 to the Edam; however, this was not significantly different from the scores for the Gouda and Cheddar at 4 months. The flavour of the three younger cheeses was preferred over those of the older cheeses. Cheddar aged to 15 months was significantly ($p<0.05$) different from the Gouda, Edam and 4 month old Cheddar; however, it was still preferred above the two Cheddars aged to 8 and 32 months, respectively. The 32 month old cheese was the least liked cheese (Table 19).

Male respondents also preferred the Edam, allocating a score of 7.29 (Table 19). Men also liked the flavour of Cheddar aged to 15 months which was characterized by young flavours. Scores for the Gouda, Edam, Cheddar at 4 months and Cheddar at 15 months were not significantly different and these four cheeses were preferred by male consumers. Scores for Cheddar aged to 8 and 32

months were not significantly different from one another. Cheddar at 32 months maturity received the lowest score.

Correlations for flavour liking were identified with the sensory attributes whey aroma (r = -0.959); bitter (r = -0.986) and prickle (r = -0.902). These negative correlations suggest that consumers did not like the attributes associated with older cheeses.

3.8.1 Partial least-squares regression performed on consumer data for flavour liking

PLS regression of the data for flavour liking generated two components that summarised both the X and Y space adequately. The PLS plot (Figure 19) shows that consumers clearly preferred the flavour characteristics of the 4 month mature Cheddar cheese. They also liked the flavour of the Gouda and Edam samples. Standardised coefficient results presented in Figure 20 suggest that the attributes cooked milk, buttery aroma, creamy aroma, creamy flavour, springiness, hardness, the instrumental colour values, i.e. L*, a*, b*, fat and salt content significantly ($p<0.05$) influenced the dependent variable of flavour.

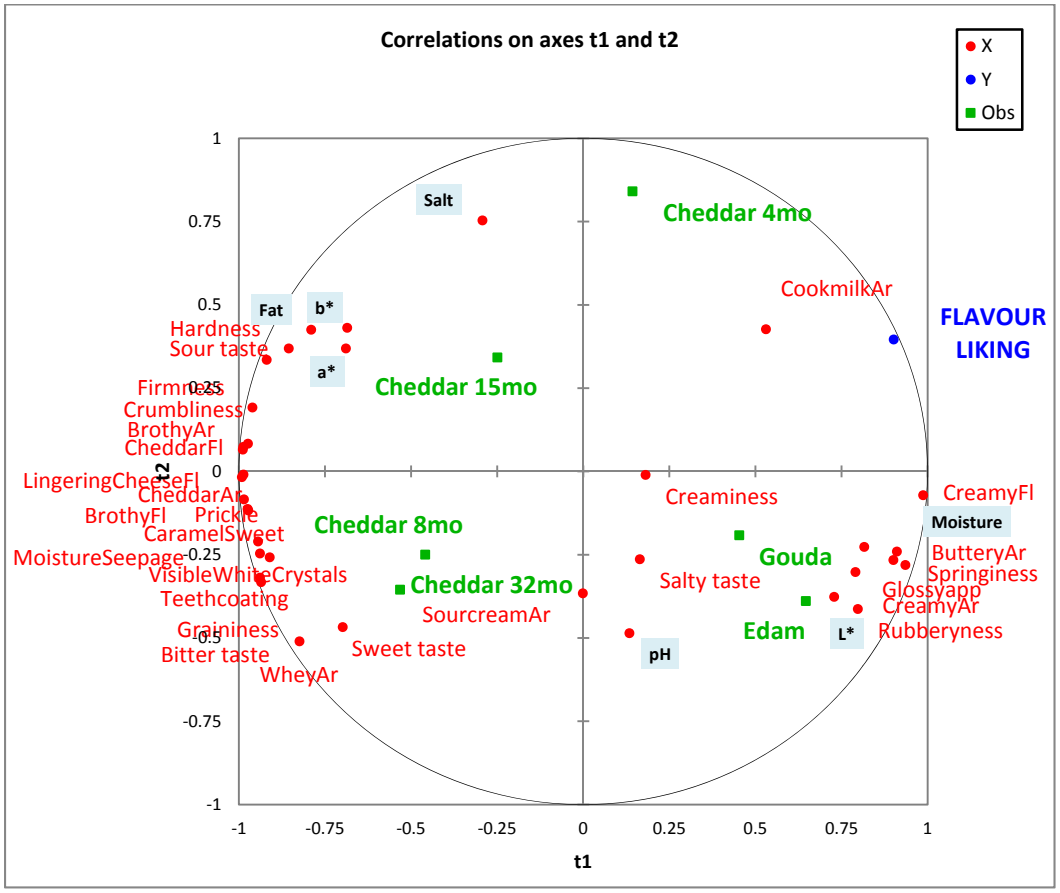

Figure 19 PLS plot indicating consumer acceptance of flavour **(BLUE)** in relation to the six cheese treatments **(Green),** and selected sensory characteristics **(Red)** and instrumental attributes **(Black). "**Ar" and "Fl" represent aroma and flavour attributes, respectively.

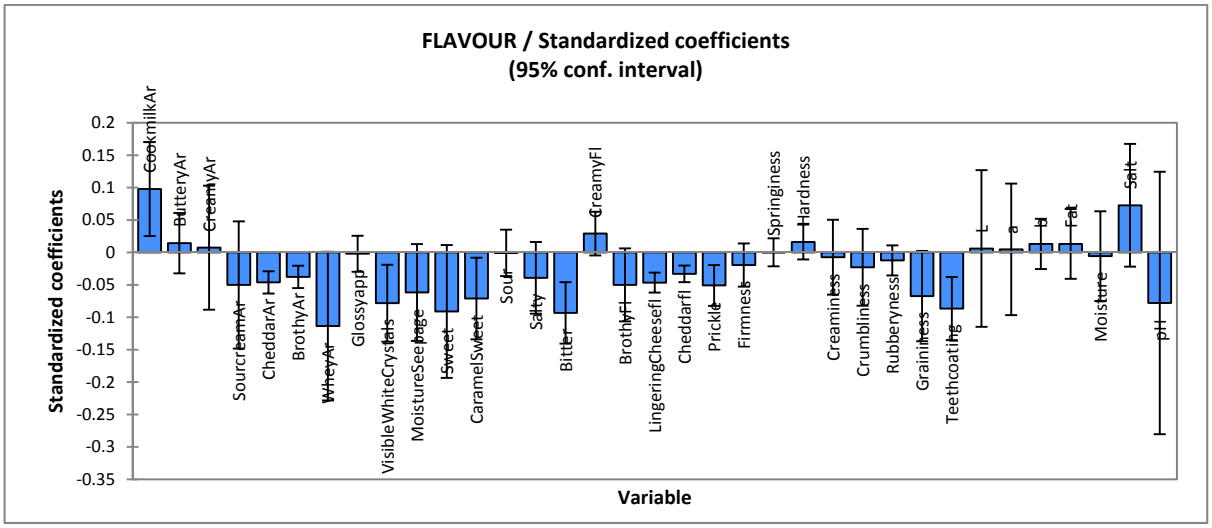

Figure 20 Standardised coefficient at a confidence interval of 95% performed on the consumer data for flavour liking. Results indicate that the attributes cooked milk aroma, buttery aroma, creamy aroma, creamy flavour, springiness, hardness, L*, a*, b*, fat and salt content significantly influenced the dependent variable of Flavour.

3.8.2 Hierarchical cluster analysis performed on the data for flavour liking of the six cheese treatments

Wards cluster analysis was performed on the consumer preference data for flavour liking (Figure 21). Three clusters were derived from the analysis for the variable flavour. The main objective of this procedure was to find similarities between the consumers based on their preference for flavour liking of the cheese samples. The similarities were then grouped together to assist in understanding any relationships that may have existed between the consumers.

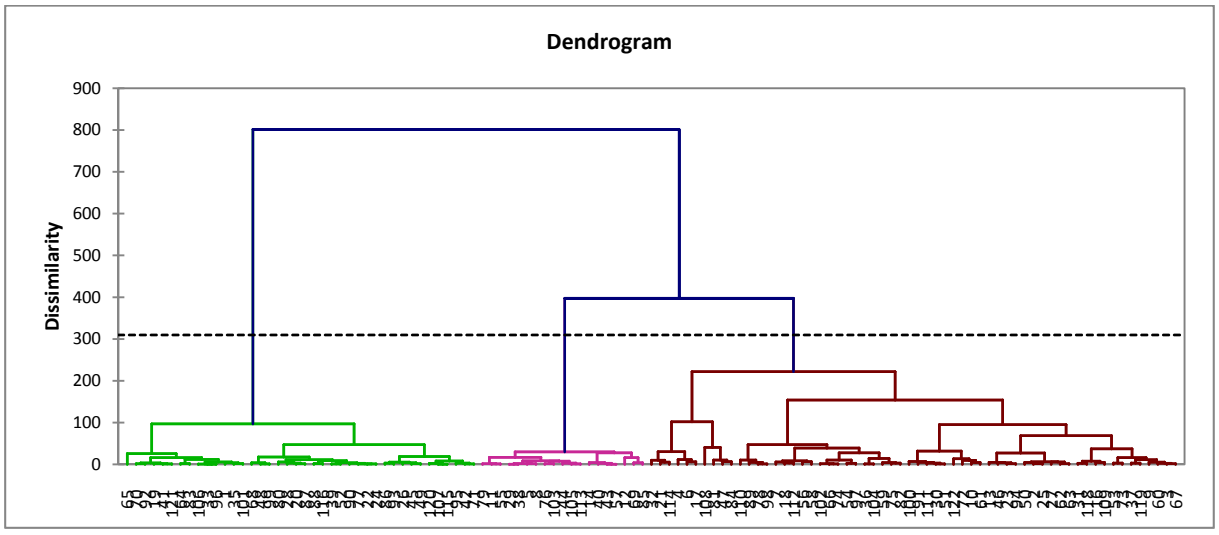

Figure 21 The dendogram of observations and sub-groups of the observations for the variable flavour of the consumer data. The dotted line represents the automatic truncation leading to the three groups.

Table 20 Details outlining the classification of each cluster based on consumer texture preference scores.

Class	1	2	3
Objects	40	60	19
Sum of weights	40	60	19
Within-class variance	8.494	20.016	7.251
Minimum distance to centroid	1.349	1.775	1.327
Average distance to centroid	2.726	4.197	2.432
Maximum distance to centroid	6.401	10.148	4.771

ANOVA was performed, at a significance level of 95% ($p<0.05$), for each one of the three clusters. If the main effect was significant, Fisher's test was performed to determine the direction of the differences between the mean values. Mean scores for flavour liking within each cluster are listed in Table 21 indicating a significant ($p<0.05$) difference in the flavour liking within each cluster.

Table 21 Mean values for flavour liking of the six cheese treatments by cluster with 1 = Dislike extremely and 9 = Like extremely.

Treatment	**Cluster 1**	**Cluster 2**	**Cluster 3**
Gouda	6. 87 [b]	6. 70 [a]	7. 33 [a]
Edam	7. 15 [b]	7. 16 [a]	7. 56 [a]
Cheddar 4mo	7. 35 [a b]	6. 86 [a]	7. 13 [a]
Cheddar 8mo	7. 11 [b]	5. 36 [b]	3. 27 [c]
Cheddar 15mo	7. 80 [a]	6. 60 [a]	4. 17 [b]
Cheddar 32mo	6. 80 [b]	4. 27 [c]	3. 50 [b c]
LSD	**0. 55**	**0. 76**	**0. 90**

[1]Least Significant Difference ($p = 0.05$)

[2] Values with the same superscript are not significantly different

Respondents in Cluster 1 preferred the flavour characteristics of the 15 month old Cheddar significantly ($p<0.05$) more than the other cheese samples (Table 21). This cheese was characterised by sour, sweet, brothy, Cheddar and prickle flavours (Chapter 3). Preference for Cheddar cheese at 4 months followed. Consumers could not differentiate between the flavour of

the Gouda, Edam, and Cheddar cheeses aged to 8 and 32 months respectively, however, flavour of these cheese samples was liked significantly less than that of the 15 and 4 month old cheeses.

Consumers in Cluster 2 significantly ($p<0.05$) preferred the flavour of the Gouda, Edam, and the two Cheddar cheeses aged to 4 and 15 month, respectively, i.e. significantly more so than the remaining cheeses (Table 21). Cheddar aged to eight months was neither liked nor disliked. Consumers disliked the flavours characterising the 32 month old Cheddar cheese. This cheese was characterised by high levels of caramel-sweet, brothy, Cheddar and prickle flavours.

Cluster 3 respondents preferred the Gouda, Edam and Cheddar cheese at 4 months significantly more than the remaining cheeses (Table 21). These samples were moderately liked and characterised by creamy flavour. The Cheddar cheeses aged to 15 and 32 months were liked significantly less. Cheddar cheese aged to eight months was significantly ($p<0.05$) the least liked cheese in this cluster and was moderately disliked by this cluster.

3.8.3 PLS regression performed on each cluster together with demographic data and consumer attitudes towards cheese

PLS regression was performed on each of the three clusters (Table 21). Demographic data and data generated from the consumer questionnaire were included in the analysis in an attempt to relate the variables to the three flavour liking clusters. Cluster dummy variables were thus used as Y input for socio-demographic and attitudinal data. In some cases, the variables of age and consumption frequency were grouped together as there were too few observations. Unfortunately there was a poor prediction of the clusters form the demographics; however, this is to be expected as the clusters were not well defined.

3.8.4 Composition of clusters for flavour liking of the six cheese treatments

Cluster 1 Cluster 1 comprised 34% of the consumers (Table 20). These consumers preferred the mild flavours typically associated with a young Cheddar cheese (Table 21). This cluster was comprised of males over the age of 25 who consumed cheese on a daily basis. Their indicated preferences for cheese type included mild, mature and extra mature Cheddar cheese, low fat cheese, mature Gouda and Edam. Cheese was consumed as a snack, in a sauce, in salads, on biscuits and as sandwich filler. Nutritional content, flavour, brand and convenience influenced the purchase decision for this cluster (Figure 22).

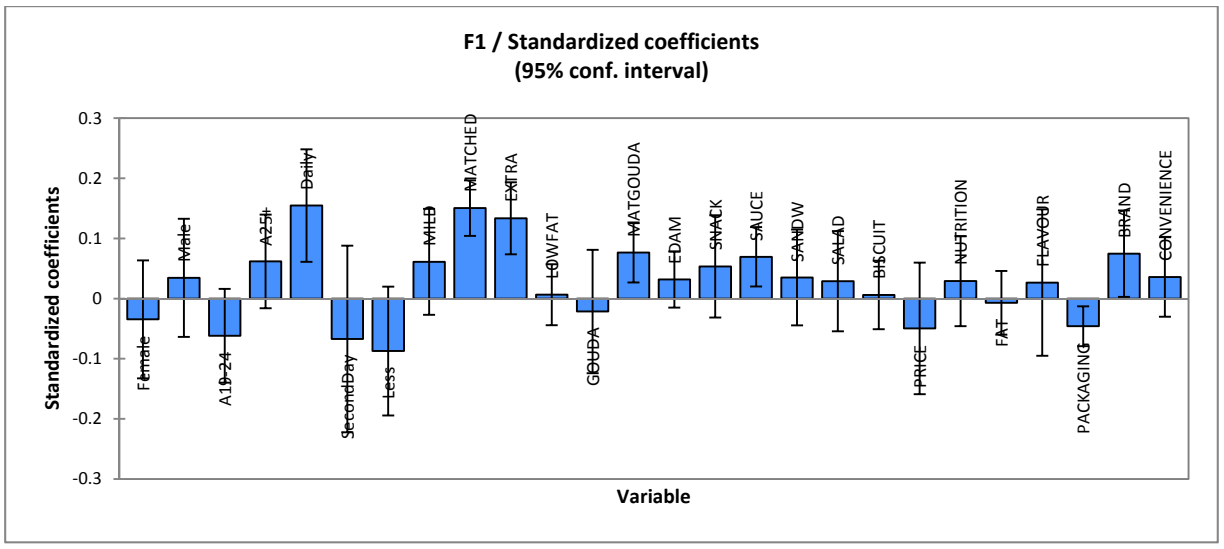

Figure 22 Standardised coefficient results for Cluster 1 based on flavour preference. Results indicate that male, age 25 +, mild Cheddar, mature Cheddar, extra mature Cheddar, low fat cheese, mature Gouda, Edam, snack, sauce, sandwich, salad, biscuit, nutrition, flavour, brand and price significantly influence the dependent variable of Flavour.

Cluster 2 Cluster 2 comprised 50% of the consumer panel (Table 20). The group was made up of females between the ages of 19 and 24 who consumed cheese every second day. This cluster liked the flavours of the Gouda, Edam, Cheddar aged to four months and the Cheddar aged to 15 months. They did not like the flavour intensity of the Cheddars aged to 8 and 32 months. This cluster indicated a preference for Edam, low fat cheese and mild Cheddar (Table 21). Cheese was consumed on biscuits, as a snack and as sandwich filler. Purchase intent was influenced by nutritional content, fat content and price (Figure 23).

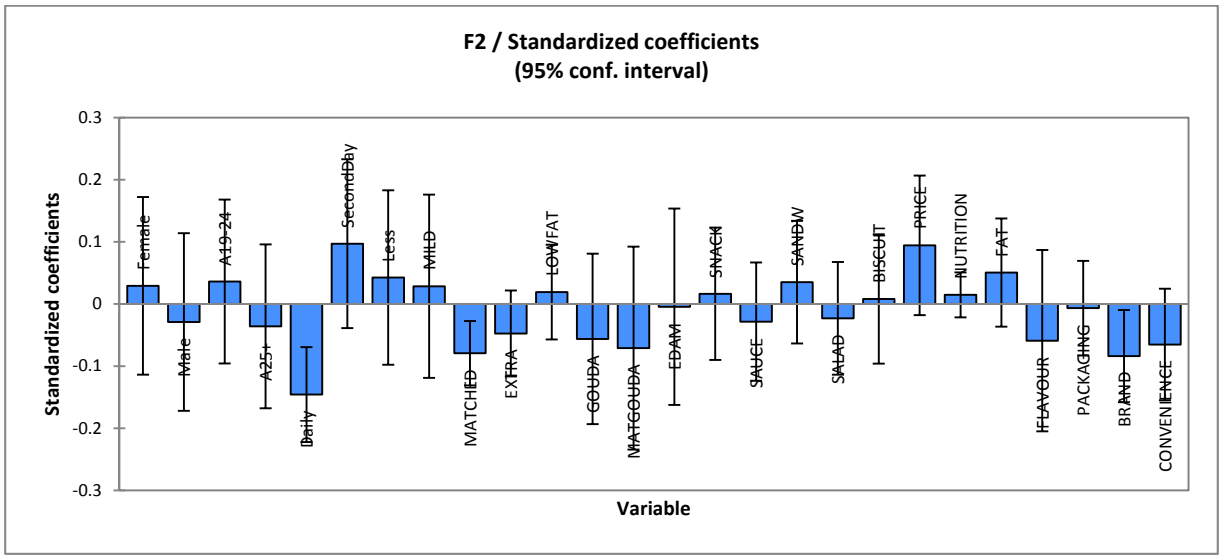

Figure 23 Standardised coefficient results for Cluster 2 based on flavour preference. Results indicate that female, age 19 – 24, consumption every second day, less frequent consumption, mild

Cheddar, low fat cheese, sauce, sandwich filler, biscuit, price, nutrition and fat content significantly influenced the dependent variable of Flavour.

Cluster 3 Cluster 3 comprised 16% of the consumer group (Table 20) and consisted of females between the ages of 19 and 24 (Figure 25). Cheese was consumed on a less frequent basis, possibly once or twice a week. These consumers preferred the flavour of the Gouda, Edam and Cheddar cheese at four months (Table 21). They did not like the Cheddar aged to eight months. Indicated cheese preference for this cluster was for Gouda and purchase intent was driven by flavour and packaging (Figure 24).

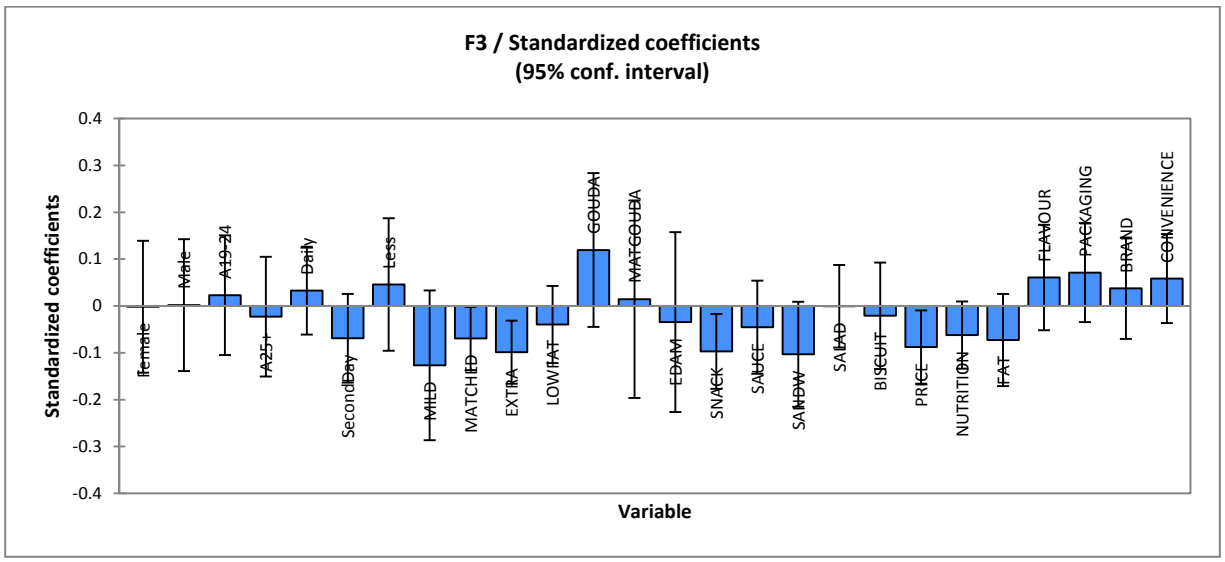

Figure 24 Standardised coefficient results for Cluster 3 based on flavour preference. Results indicate that male, age 19 – 24, daily consumption, less frequent consumption, Gouda, mature Gouda, flavour, packaging, brand and convenience significantly influenced the dependent variable of Flavour.

3.8.5 Product optimisation per cluster

Based on the PLS performed on the hedonic data for flavour liking and the subsequent cluster analysis, product optimisation per cluster is detailed below (Figures 25, 26 and 27). Also refer to Table 22 for a summary of factors affecting liking of flavour of the three clusters.

Optimised flavour for Cluster 1 Cheddar cheeses in particular, characterised by young and developing aged flavours would appeal to this group. Cheeses described by creamy, sour, sweet together with slight brothy, Cheddar and prickle flavours would be optimised for this cluster of male

consumers. Furthermore, cheeses with this flavour development would be appropriate, as the indicated preference for this cluster was mild, mature and extra mature Cheddar, mature Gouda and Edam cheese. As brand is a key driver in the cheese purchase decision, specific flavour characterisation should be associated with the brand. In addition, the cheese would have to satisfy consumer needs for a convenient and nutritional product offering.

Optimised flavour for Cluster 2 Cheeses characterised by young and undeveloped flavours would appeal to this cluster. Chesses characterised by high intensities of aged flavours including caramel sweet, brothy, Cheddar and prickle would be rejected. A cheese described by high levels of creaminess and buttery flavour would be optimised for this cluster of young females who consume cheese every second day. This type of cheese compares favourably with the indicated preference for mild and low fat cheeses which are generally characterised by young and undeveloped flavours. The product offering would have to promote the nutritional benefits of the cheese above the fat content to encourage additional consumption.

Optimised flavour for Cluster 3 Cheeses characterised by young and undeveloped flavours would appeal to this cluster. Chesses characterised by high intensities of aged flavours including caramel sweet, brothy, Cheddar and prickle would be rejected outright. It is interesting to note that this group of male consumers indicated Gouda and mature Gouda cheeses as their preferred cheese. Gouda is generally characterised by young and undeveloped flavours, however, mature Gouda is characterised as having higher intensities of aged flavours which were not accepted by this cluster. Furthermore, consumption levels of cheese were low for this group as they only consumed cheese once or twice a week. The method of consumption was not specified; however flavour is a key driver in the cheese purchase decision. Emphasis should therefore be placed on the specific flavour characterisation of the product to satisfy the sensory requirements of this cluster. Packaging and convenient also play a role.

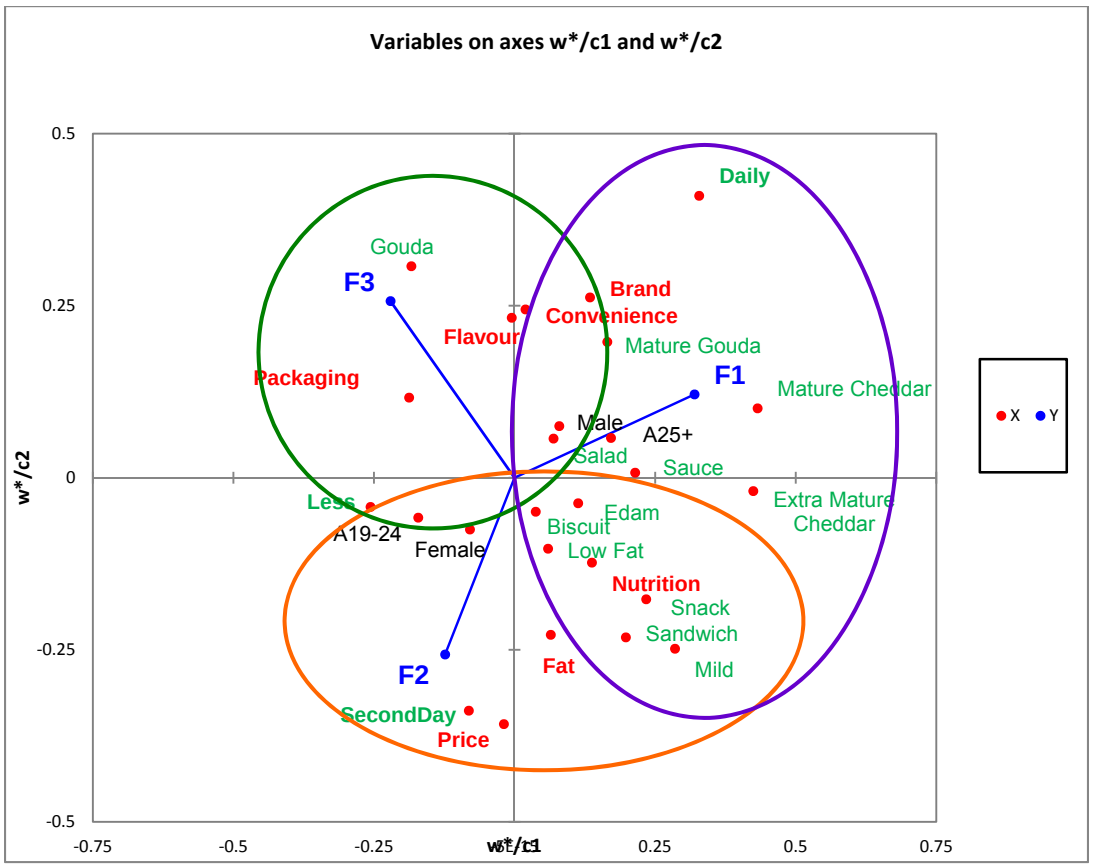

Figure 25 PLS plot showing the relationship between each cluster based on flavour preference. The map includes socio-demographic data **(Black)**, consumption data **(Green)** and factors influencing purchase intent **(Red)**.

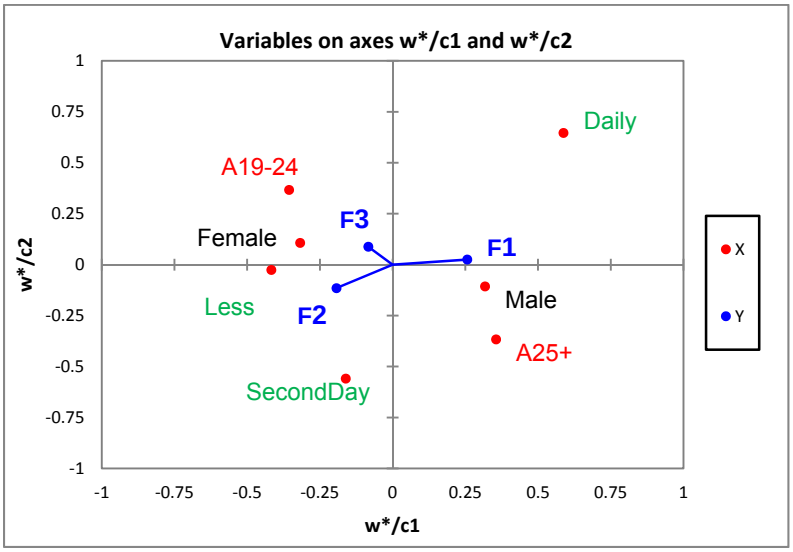

Figure 26 PLS plot illustrating the relationship between each cluster **(F1, F2 and F3)**, for flavour liking, gender **(Black)**, age **(Red)** and frequency of consumption **(Green)**.

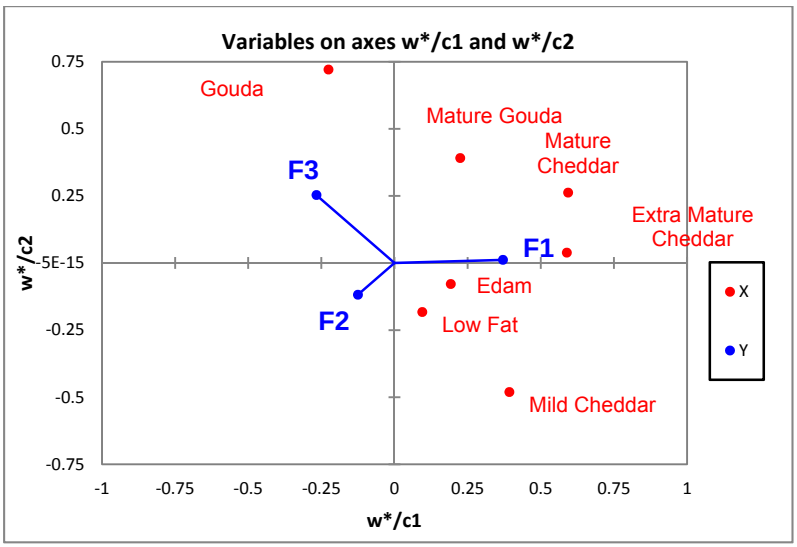

Figure 27 PLS plot illustrating the relationship between each cluster **(F1, F2 and F3)** for flavour liking of the cheese and indicated preference for cheese type **(Red)**.

Table 22 Summary of the features characterising each cluster based on hedonic scores for flavour liking.

	Cluster 1	Cluster 2	Cluster 3
Cheese preference identified from hedonic scores in consumer analysis.	Preferred the flavour of Cheddar aged to 15 months followed by Cheddar aged to four months, but could not clearly distinguish between the flavour of the remaining cheese samples. The low score for Gouda flavour is noteworthy.	Preferred the flavour of the Edam, Cheddar aged to four months, Gouda and Cheddar at 15 months equally. The Cheddar at eight months was neither liked nor disliked while the Cheddar aged to 32 months was the least liked cheese.	Preferred the flavour of the Gouda, Edam and Cheddar aged to four months followed by the Cheddar aged to 15 months. Did not like the Cheddar aged to 32 months and the Cheddar aged to eight months was the least liked cheese.
Sensory description of the cheese flavour	Cheddar aged to 15 months characterised by creamy, sour, sweet, slight brothy, slight Cheddar and slight prickle attributes.	Gouda, Edam and Cheddar cheeses aged to four and 15 months characterised by high levels of creaminess and young cheese flavours. Cheddar aged to 32 months characterised by high levels of caramel sweet, brothy, Cheddar and prickle flavours.	Gouda, Edam and Cheddar cheeses aged to four and 15 months characterised by high levels of creaminess and young cheese flavours. Cheddar aged to 8 months characterised by high levels of caramel sweet, brothy, Cheddar and prickle flavours.
Size of Cluster	34% of the consumer panel.	50% of the consumer panel.	16% of the consumer panel
Gender composition	Male	Female	Male
Age	25 years and older	19 – 24 years	19 – 24 years
Consumption of cheese	Daily	Every second day	Once or twice a week
Indicated preference for cheese	Mild, mature and extra mature Cheddar, mature Gouda and Edam	Mild Cheddar and low fat cheese	Gouda and mature Gouda
Way in which cheese consumed	Sandwich filler, snack and sauce ingredient	Sandwich filler, snack and on biscuits	None identified
Factors influencing purchase intent	Brand, convenience, nutritional offering and flavour	Fat content and nutrition	Packaging, flavour, brand and convenience

3.9 Consumer hedonic responses to the overall liking of the six cheese samples.

Results of the consumer acceptance testing of overall liking for the six cheese treatments are discussed in the paragraphs below. ANOVA results, i.e. significant differences between treatment means for the total group as well as male and female consumers are indicated in Table 23

Table 23 Mean values for consumer overall liking of the six cheese treatments with 1 = Dislike extremely and 9 = Like extremely.

Treatment	All consumers	Female consumers	Male consumers
Gouda	7. 32 [a]	7. 21 [a]	7. 50 [a]
Edam	7. 38 [a]	7. 39 [a]	7. 36 [a b]
Cheddar 4mo	7. 11 [a]	7. 00 [a]	7. 29 [a b]
Cheddar 8mo	5. 65 [c]	5. 14 [c]	6. 47 [c]
Cheddar 15mo	6. 24 [b]	5. 88 [c]	6. 81 [b c]
Cheddar 32mo	4. 95 [d]	4. 45 [d]	5. 77 [d]
LSD	**0. 43**	**0. 57**	**0.** 63

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

According to Table 23 the Gouda, Edam and 4 month mature Cheddar cheese were all equally liked by the total group of consumers. These cheeses were characterized by young flavours of creamy and buttery determined by DSA and reported in Chapter 3. Cheddar matured to 15 months, an older cheese described by predominantly young flavours, was also liked by total group of consumers, although to a lesser degree than the three young cheeses. Cheddar cheeses at 8 and 32 months were less liked. Cheddar aged to 32 months received the lowest score for overall liking.

Female respondents followed a similar trend. Edam received the highest score; however, this was not significantly different from scores for the Gouda and 4 month old Cheddar. This suggests that female consumers in this study preferred cheeses characterised by young flavours of creamy and buttery. Cheddar at 15 months maturity was neither liked nor disliked and Cheddar aged to 32 months was disliked slightly. Male respondents clearly preferred the Gouda. This was followed by Edam and four month mature Cheddar. Cheddar at 15 months was also liked, however, to a lesser degree. Cheddar aged to 8 months was preferred above Cheddar matured to 32 months. These results suggest that male consumers in this testing also preferred cheeses characterized by young flavours. Significant correlations for flavour liking were identified with Cheddar aroma (r = -0.950); brothy aroma (r = -0.928); whey aroma (r = - 0.909); bitter (r = -0.996); brothy flavour (r = 0.935); Cheddar flavour (r = -0.919); prickle (r = -0.945). It is clear from the correlation analysis that consumers in this study preferred the younger cheese flavour and texture. As the cheeses aged and developed mature flavours (Drake *et al.*, 2001) acceptance of the product declined.

3.9.1 Partial least-squares regression performed on consumer data for overall liking

PLS regression for overall liking generated two components that summarised both the X and Y space adequately. The PLS plot (Figure 28) shows that consumers preferred the Gouda, Cheddar at 4 months maturity and the Edam cheese above the Cheddar cheeses 8 to eight, 15 and 32 months. Standardised coefficient results shown in Figure 29 indicate that the dependent variable Overall Liking was significantly ($p<0.05$) influenced by the attributes cooked milk aroma, buttery aroma, creamy aroma, glossy appearance, creamy flavour, springiness, creaminess, instrumental colour values L*, a* and b*, fat content, moisture content and salt content. In this study consumers indicated a preference for attributes generally identified in young cheese (Drake *et al*., 2001) with high intensities of cooked milk, buttery and creamy aroma, a glossy appearance, creamy flavour and a texture characterised by springiness and creaminess. Compositional factors of fat, moisture and salt content contributed to the overall consumer preference, as well as instrumental readings for colour. Consumers also rejected the flavours generally associated with aged cheese characterised by brothy, Cheddar and whey aroma, brothy, sweet, caramel, prickle and lingering cheese flavour; hardness, firmness, crumbliness and teeth-coating attributes.

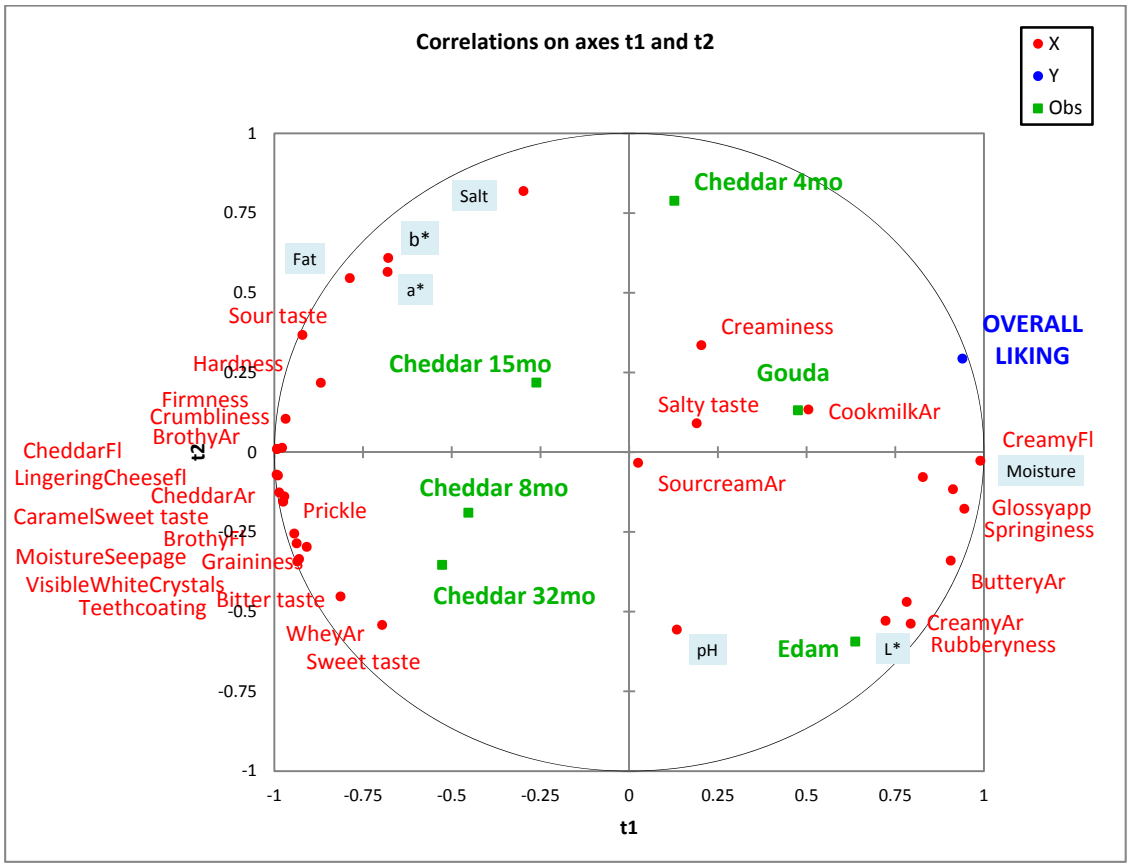

Figure 28 PLS plot indicating overall degree of liking **(BLUE)** in relation to the six cheese treatments **(Green),** and selected sensory characteristics **(Red)** and instrumental attributes **(Black). "**Ar" and "Fl" represent aroma and flavour attributes, respectively.

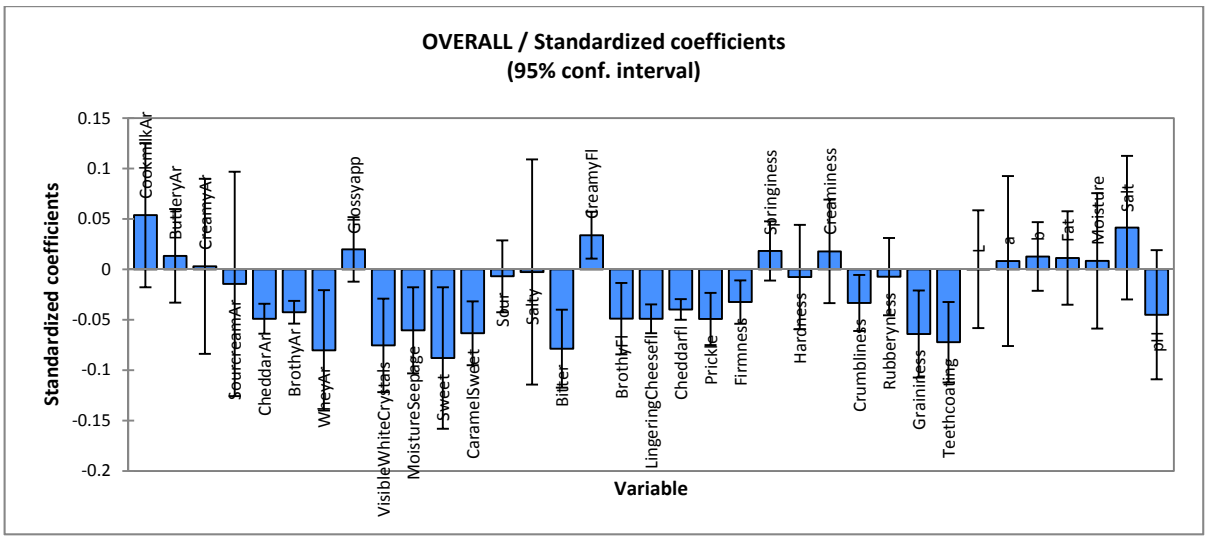

Figure 29 Standardised coefficients at a confidence interval of 95% performed on the consumer data for overall liking. Results indicate that cooked milk aroma, buttery aroma, creamy aroma, glossy appearance, creamy flavour, springiness, creaminess, L*, a*, b*, fat content, moisture content and salt content significantly influenced the dependent variable of Overall liking.

3.9.2 Hierarchical cluster analysis performed on the preference data for the overall liking of the six cheese treatments

As indicated in the previous divisions Wards cluster analysis was also performed on the overall liking data. Three clusters were derived from the analysis for the variable Overall Liking (Figure 30).

ANOVA was also again performed on the cluster data. If the main effect was significant, Fisher's test was performed to determine the direction of the significant differences between the mean values at the 95% significance level. Mean scores for Overall Liking within each cluster are listed in Table 23. A significant difference in the Overall liking was identified within each cluster.

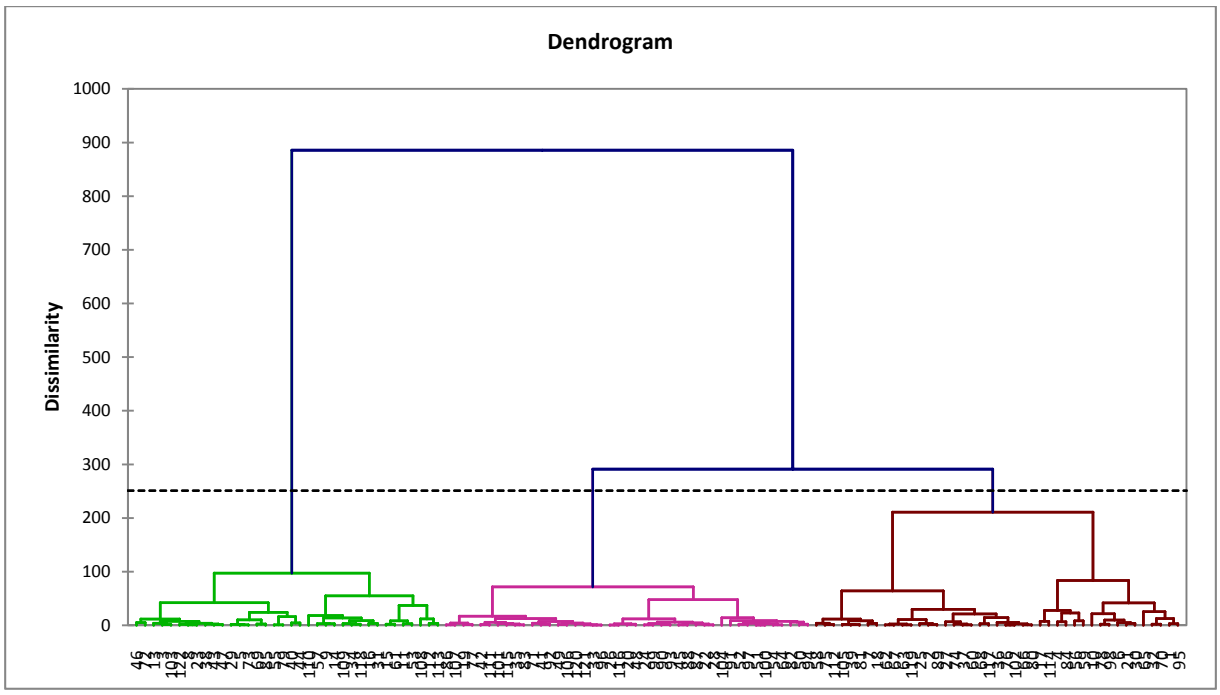

Figure 30 The dendogram of observations and sub-groups of the observations for the variable overall degree of liking of the consumer preference data. The dotted line represents the automatic truncation leading to three groups.

Table 24 Details outlining the classification of each cluster based on consumer overall liking scores.

Class	1	2	3
Objects	43	36	43
Sum of weights	43	36	43
Within-class variance	16.632	11.911	6.639
Minimum distance to centroid	1.039	1.119	1.143
Average distance to centroid	3.757	3.219	2.436
Maximum distance to centroid	7.595	6.239	4.979

Table 25 Mean values for overall liking of the six cheese samples by cluster with 1 = Dislike extremely and 9 = Like extremely.

Treatment	Cluster 1	Cluster 2	Cluster 3
Gouda	6. 79 [a]	7. 52 [a]	7. 51 [a]
Edam	7. 14 [a]	7. 61 [a]	7. 44 [a]
Cheddar 4mo	6. 81 [a]	6. 69 [b]	7. 67 [a]
Cheddar 8mo	6. 02 [b]	2. 89 [d]	7. 49 [a]
Cheddar 15mo	6. 74 [a]	4. 31 [c]	7. 44 [a]
Cheddar 32mo	4. 44 [c]	2. 58 [d]	7. 53 [a]
LSD	**0. 71**	**0. 67**	**0. 43**

[1]Least Significant Difference (p = 0.05)

[2] Values with the same superscript are not significantly different

According to Table 25 respondents in Cluster 1 preferred the Edam, Gouda and the two Cheddar cheeses aged to 4 and 15 months, respectively. Although the Edam received the highest score of 7.14, indicating that it was moderately liked by consumers, it was not significantly different from the remaining three cheeses. Consumers indicated that the Cheddar cheese aged to eight months was liked slightly, however, to a lesser degree than Edam, Gouda and Cheddars at 4 and 15 months. The Cheddar aged to 32 months was the least liked cheese and received a score of 4.44 indicating that it was disliked slightly. These results suggest that consumers in Cluster 1 preferred the undeveloped flavours frequently identified in younger cheeses (Drake *et al.*, 2001).

Consumers in Cluster 2 preferred the Edam and Gouda cheeses above the Cheddar cheeses aged to 4 and 15 months (Table 25). This group also clearly disliked the Cheddar cheeses aged to 8 and 32 months. These two cheeses were characterised as having high intensities of aged flavours (Drake *et al.*, 2001). These results suggest that consumers in Cluster 2 also preferred the undeveloped flavours frequently identified in younger cheeses, however, they also indicated a high level of dislike for the intensity of flavours often identified in aged Cheddar cheese (Drake *et al.*, 2001).

Respondents in Cluster 3 could not differentiate between the six samples of cheese (Table 25). All samples received the same score, indicating that they were liked moderately ($p>0.05$).

3.9.3 PLS regression performed on each cluster together with demographic data and consumer attitudes towards cheese

PLS regression was conducted on each of the three clusters (Table 25). Demographic data and data generated from the consumer questionnaire were included in the analysis in an attempt to relate the variables. Cluster dummy variables were used as Y input for social-demographic and

attitudinal data. In some cases, the variables of age and consumption frequency were grouped together as there were too few observations. Unfortunately there was a poor prediction of the clusters from the demographics; however, this is to be expected as the clusters were not well defined. Briefly, Cluster 1 was made up of young, health conscious women whose buying decision was driven by price. Cluster 2 was also made up of young women; however, their consumption of cheese was low and their buying decision driven by flavour. Cluster 3 comprised males, over the age of 25, whose cheese consumption was high. They enjoyed all types of cheese. Buying decision for Cluster 3 was driven by flavour and brand.

3.9.4 Composition of clusters for overall liking of the six cheese treatments

Cluster 1 Cluster 1 for overall liking was made up of 35% of the consumer panel respondents (Table 24). This cluster did not like the Cheddar cheeses at 8 and 32 months maturity (Table 25). This group consisted mainly of females between the ages of 19 and 24. They consumed cheese every second day and indicated a preference for mild Cheddar and low fat cheese. Generally they consumed cheese as a snack, as sandwich filler and as part of a salad. Price, nutritional offering and fat content influenced their purchase intent when buying cheese (Figure 31).

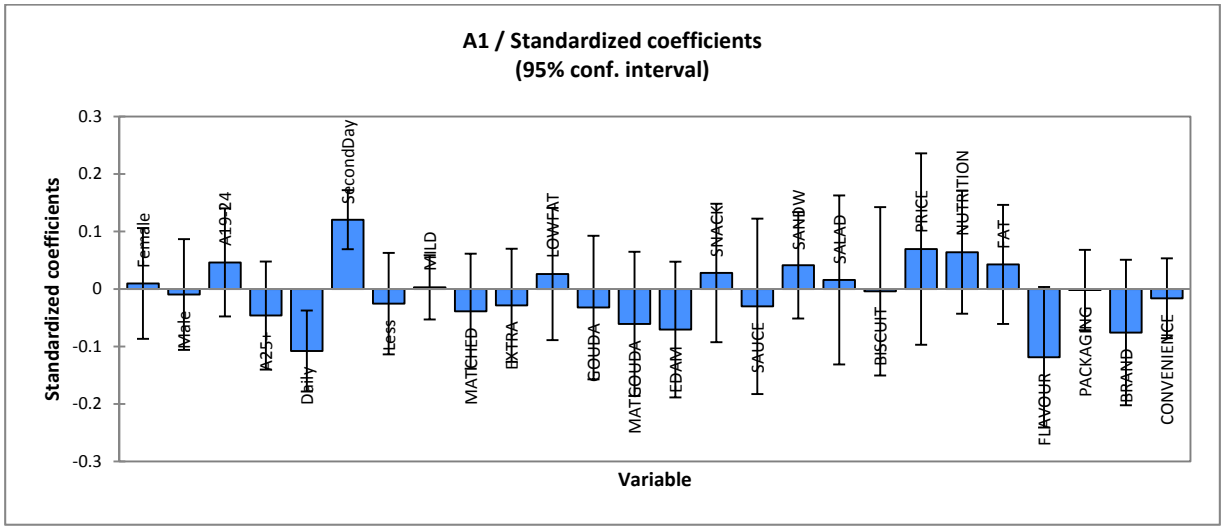

Figure 31 Standardized coefficients for Cluster 1 based on overall liking. Results indicate that female, aged 19 – 24, second day, mild, low fat, snack, sandwich, salad, price, nutrition, fat content significantly influenced the dependent variable of Overall liking.

Cluster 2 Cluster 2 was made up of 30% of the consumer participants (Table 24). Of the six cheese samples, this cluster liked the Gouda and Edam cheeses, followed by the Cheddar aged to 4 months. Cheddar at 15 months was also liked, however, to a lesser degree. Cheddar at 8 and 32 months were liked significantly ($p<0.05$) less that the remaining four cheeses (Table 25). They were female and aged between 19 and 24 years of age. This cluster consumed cheese on a less frequent basis, i.e. once or twice a week. They indicated a preference for Gouda and Edam

cheese and generally consumed cheese as a salad ingredient. Flavour, packaging, brand and convenience influenced their cheese buying decisions (Figure 32).

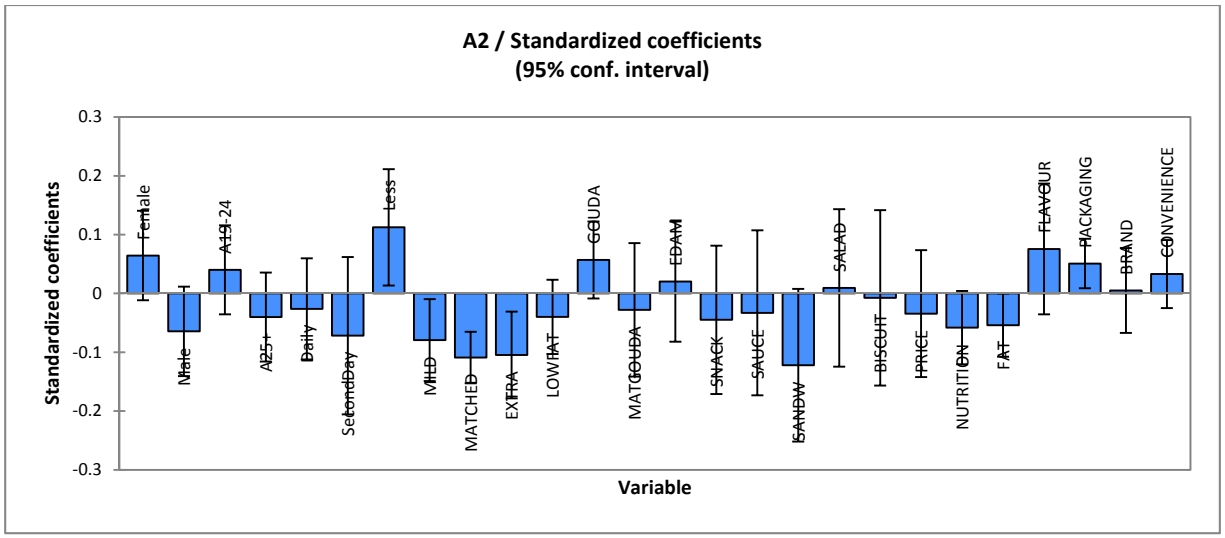

Figure 32 Standardized coefficients for Cluster 2 based on overall liking. Results indicate that female, aged 19 – 24, less often consumption of cheese, Gouda, Edam, salad, flavour, packaging, brand, and convenience significantly influenced the dependent variable of Overall liking.

Cluster 3 Cluster 3 comprised 35% of consumer panel (Table 24). The cluster was made up of males over the age of 25 who consumed cheese on a daily basis (Figure 33). This cluster in particular could not distinguish between any of the six cheese samples (Table 25). This cluster indicated a preference for mild, mature and extra mature Cheddar and to a lesser degree Edam and low fat cheese. They consumed cheese as a snack, in a sauce, as sandwich filler and on biscuits. Purchase intent was driven by flavour and brand and to a lesser degree fat content.

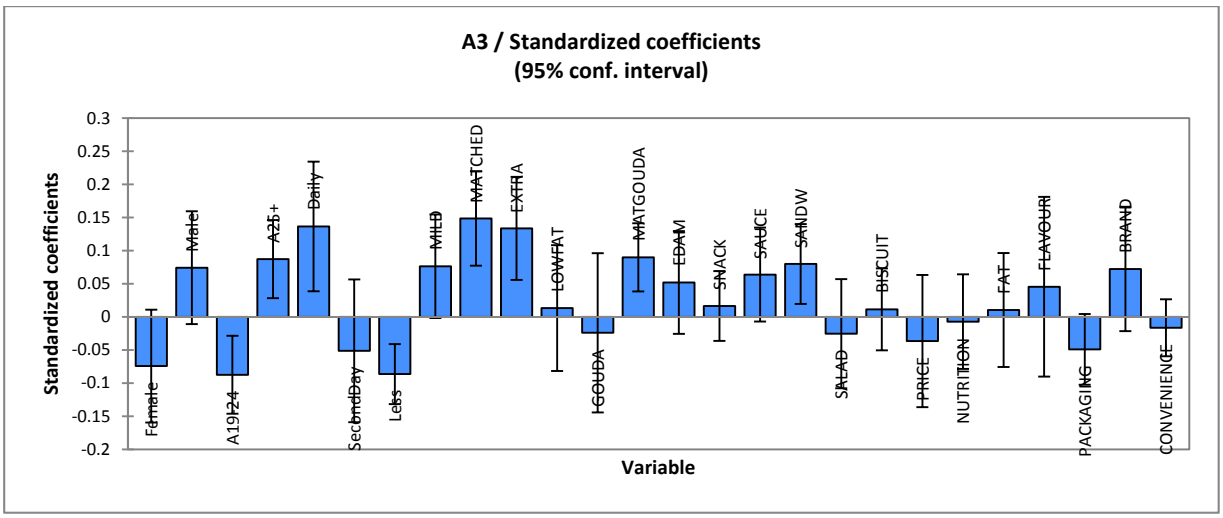

Figure 33 Standardized coefficients for Cluster 3 based on overall liking. Results indicate that male, 25+, mild, mature Cheddar, Extra mature Cheddar, Edam, snack, sauce, sandwich, biscuit, fat content, flavour and brand significantly influenced the dependent variable of Overall liking.

3.9.5 Product optimisation per cluster

The ability of a company to produce a product which satisfies the sensory requirements of a consumer has a distinct lead to success and profitability (McEwan, 1996). Based on the PLS performed on the hedonic data for overall liking (Table 25) and the subsequent cluster analysis, product optimisation per cluster is detailed below (Figures 34, 35 and 36). Also refer to Table 26 for a summary of factors affecting overall liking of the cheese per cluster. Each cluster represents approximately 30% of the consumers, indicating that for Overall Liking, the clusters are well represented.

Optimised Cheese for Cluster 1 Cheeses characterised by young flavours and texture would appeal to this cluster. Often described by attributes of glossy appearance, creamy and buttery aromas, creamy and slightly sour flavours together with springy, rubbery and creamy textures, young cheeses are optimised for this group of female consumers. Furthermore young cheeses with undeveloped flavours would be most appropriate as the indicated cheese preference for this cluster was mild Cheddar and low fat cheeses. Since cheese is only eaten every second day, the product offering could be made more attractive by emphasising the nutritional benefits above the fat content of the cheese. Price, however, remains the key driver in the purchase decision so any promotional effort should highlight value for money.

Optimised Cheese for Cluster 2 Cluster 2 also preferred cheeses characterised by young flavour and texture development. They were differentiated from Cluster 1 however, by their dislike of the flavours and textures that characterise aged cheeses. Cheeses therefore described by attributes of visible white crystals, moisture seepage, brothy and Cheddar aromas, caramel-sweet,

lingering cheese, Cheddar and prickle flavours together with hard, firm, grainy, crumbly textures would be rejected. As consumption of cheese is low in this cluster, promotional efforts would have to focus on the flavour offering in combination with packaging that satisfies this specific segment. Moreover, efforts to include cheese as a convenient snack or sandwich filler may also increase consumption.

Optimised Cheese for Cluster 3 All cheese types would appeal to this cluster. Any cheese characterised by either young and undeveloped or aged attributes would be optimised for this group of male consumers. Fortunately, this segment consumes cheese on a daily basis as a snack, sandwich filler and on biscuits. Brand and cheese flavour are the two key drivers in the cheese purchase decision.

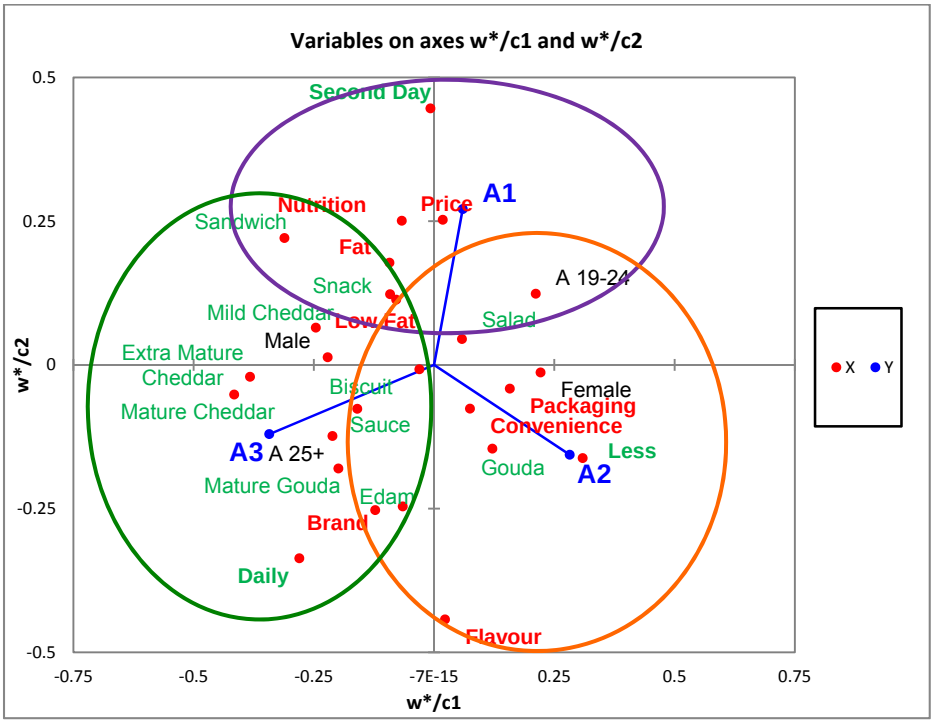

Figure 34 PLS plot illustrating the relationship between each cluster based on overall liking. The map includes socio-demographic data **(Black)**, consumption data **(Green)** and factors influencing purchase intent **(Red)**.

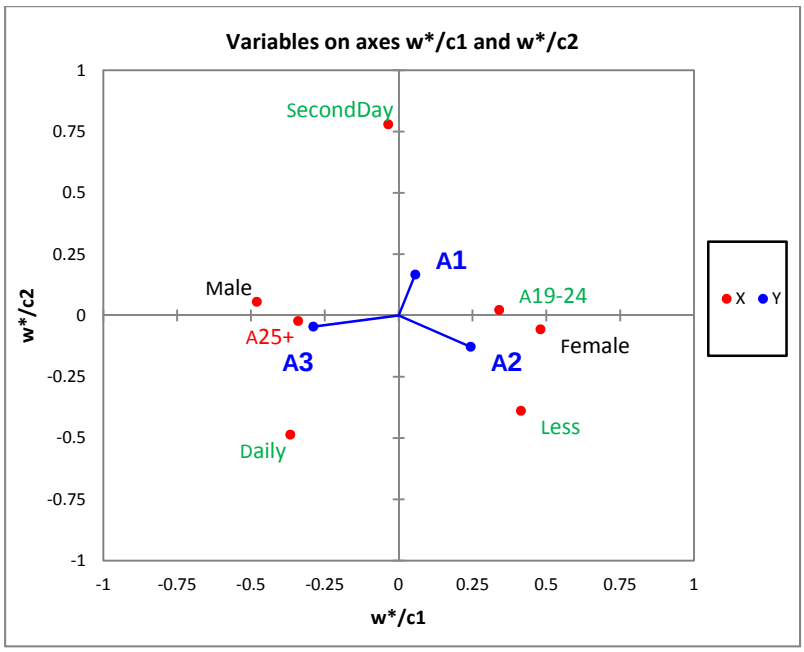

Figure 35 PLS plot showing the relationship between each cluster **(A1, A2 and A3)** for overall preference, gender **(Black)**, age **(Red)** and frequency of consumption **(Green)**.

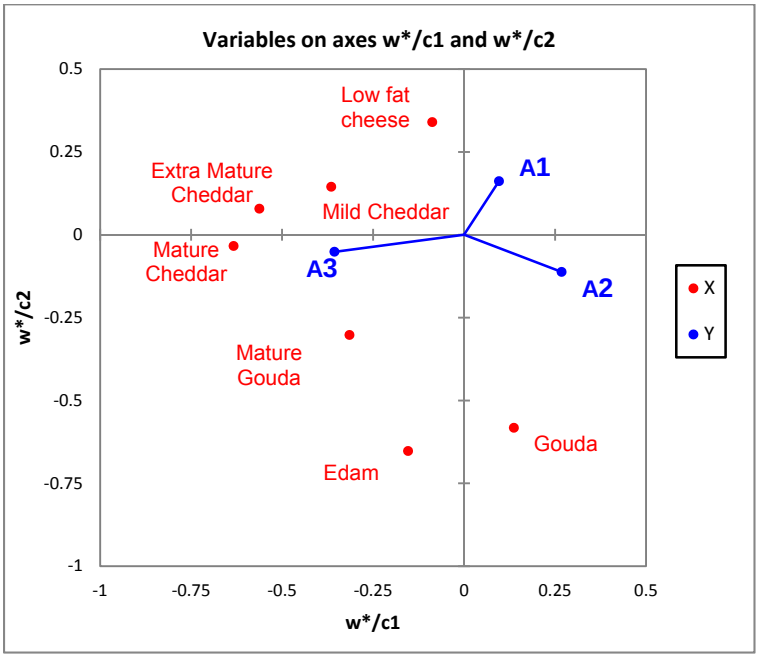

Figure 36 PLS plot showing the relationship between each cluster **(A1, A2 and A3)** for overall liking of the cheese and indicated preference for cheese type **(Red)**.

Table 26 Summary of the features characterising each cluster based on hedonic scores for overall liking.

	Cluster 1	Cluster 2	Cluster 3
Cheese preference identified from hedonic scores in consumer analysis.	Edam, Gouda, Cheddar aged to four months and Cheddar aged to 15 months.	Edam and Gouda with a distinct dislike of Cheddar cheeses aged to eight and 32 months.	Liked all cheese samples. Could not differentiate between the samples.
Sensory description of the cheese	Cheeses characterised predominantly by buttery and creamy aroma, creamy flavour; springy, rubbery and creamy textures.	Cheddar cheeses aged to eight and 32 months characterised by dull surface with visible white crystals and moisture seepage, brothy and Cheddar aromas, caramel sweet, brothy, lingering cheese, Cheddar and prickle flavours; hard, firm, grainy, crumbly and mouth-coating texture.	
Size of Cluster	35% of total consumer panel.	30% of total consumer panel.	35% of total consumer panel.
Gender composition	Female	Female	Male
Age	19 - 24	19 - 24	25 years and older
Consumption of cheese	Every second day	Once or twice a week	Daily
Indicated preference for cheese	Mild Cheddar and low fat cheese	Gouda and Edam	Mild, mature and extra mature Cheddar followed by Edam and to a lesser degree low fat cheese
Way in which cheese consumed	Snack, sandwich filler and in a salad	As part of a salad	Snack, sandwich filler, sauce and on biscuits
Factors influencing purchase intent	Price, nutritional offering and fat content	Flavour followed by packaging, brand and convenience	Flavour and brand followed by fat content

4. CONCLUSIONS

Optimizing the flavour of Cheddar cheese to improve consumer acceptance and consumption requires a combination of sensory (Chapter 3) and consumer analysis techniques (Chapter 6). These two sets of data complement one another to maximise available information in identifying those sensory aspects of the cheese that satisfy consumer requirements.

Partial least-squares regression performed on the sensory descriptors characterising six cheese treatments and the consumer acceptance data from 115 consumers effectively identified the key drivers of consumer liking for cheese colour, texture, flavour and overall characteristics of the cheeses. Hierarchical cluster analysis performed on each of the same variables (colour, texture, flavour and overall) identified three clusters of consumers with similar preferences per variable. Analysis of variance conducted on the consumer acceptance data identified the cheese preferences per cluster. Further PLS regression performed on the demographic and attitudinal data in conjunction with the consumer acceptance data per cluster identified consumers with specific sensory requirements for cheese. The results distinguished cheese characteristics that could be optimised to satisfy specific consumer segments.

The most popular cheese across age and gender for participants in this study and based on their indicated cheese preference was Gouda, followed by mild Cheddar cheese. Males indicated a higher preference for mature and extra mature cheeses while females tended to prefer low fat and Edam cheese. Young respondents disliked extra mature Cheddar cheese. Cheese was most often consumed as sandwich filler and on biscuits. Cheese purchase intent for all consumers across age and gender was driven by flavour and price. Neither the younger nor the older group of consumers considered fat content and the nutritional offering important aspect in the purchase decision of cheese. Convenience however was an important consideration for the older consumers albeit to a lesser degree than price and flavour.

PLS results demonstrated that key drivers for colour liking were creamy texture, salty, sour cream aroma, and the two instrumental colour attributes a* (redness) and b* (yellowness). Male consumer liked coloured and uncoloured cheese equally, while female respondents preferred a coloured cheese. The most liked cheese colour was for the Gouda followed by the Cheddar aged to four months. From a sensory perspective, the Gouda was described as having a glossy appearance. It would seem then that glossiness plays an important role in the consumer liking of cheese colour.

Three clusters of consumers were identified based on their colour liking scores. Cluster 1, comprising 53% of the consumer group, consisted of males over the age of 25. The optimised product for this cluster would be a coloured cheese with a glossy appearance. Cluster 2, comprising 41% of the consumer group and consisting of females between the ages of 19 – 24 liked both coloured and uncoloured cheeses. They indicated a dislike of aged cheeses described

as dull with visible white crystals and moisture seepage. An optimised cheese would be coloured or uncoloured with a slightly glossy appearance. Cluster 3 comprised only 6% of the consumer group and consisted of females between the ages of 19 – 24. These consumers preferred an uncoloured cheese and disliked aged cheeses described as dull with visible white crystals and moisture seepage. An uncoloured cheese with a glossy appearance would be optimised for this cluster.

Texture liking results suggest that consumers prefer a cheese characterised by springy, firm, rubbery and creamy textural attributes. The most liked cheeses, the Gouda, Edam and the Cheddar aged to four months were characterised by these attributes. Consumers, however, did not like the grainy, crumbly and teeth-coating textural attributes that described the aged Cheddar cheeses. Female texture liking followed a similar trend. Males on the other had preferred the Edam and four month mature Cheddar texture above the Gouda texture. In addition, males did not indicate a distinct dislike of the older cheese textures. Results from the PLS analysis revealed that cooked milk aroma, salt, creamy flavour, fat content and buttery aroma significantly drive texture liking. Of the textural attributes, springiness it seems exerted the most influence over texture liking.

Three clusters were identified based on the data for consumer texture liking. Cluster 1, comprising 38% of the consumer panel consisted of males over the age of 25 who consumed cheese on a daily basis. This group could not distinguish between the textures of the six cheese samples and indicated a moderate liking for all cheese samples. The Cheddar aged to 32 months was significantly less liked than the other cheese textures. Cluster 2 comprised 37% of the consumer panel and also consisted of males over the age of 25. These consumers ate cheese every second day. Their textural preferences were for the Edam and Cheddar aged to 4 months; the texture of the Cheddar aged to 32 months was not liked. Cluster 3 preferred the texture of the Gouda, Edam and Cheddar aged to 4 months. This group comprised 25% of the consumer panel and consisted of females aged between 19 – 24 years. An optimised cheese for both Cluster 2 and 3 would be characterised as rubbery, springy and creamy texture.

Consumers preferred the flavours identified in the young cheeses. Gouda, Edam and Cheddar aged to 4 months were equally liked. Female flavour liking followed the same trend while also indicating a dislike of the flavour of the Cheddar aged to 32 months. Males liked the Gouda, Edam and Cheddar aged to 4 months, however, their preferences also included the Cheddar aged to 15 months. These four cheeses were characterised by creamy, sour, sweet, slight brothy, slight Cheddar and slight prickle flavours. The aged Cheddar cheese samples were characterised by high levels of caramel sweet, brothy, Cheddar and prickle flavours. Results from the PLS analysis indicated that flavour liking was driven by cooked milk aroma, salt content, creamy flavour, hardness and buttery aroma. Cooked milk and buttery aroma together with creamy flavour were identified in higher intensities in the most liked cheese samples, that is, the Gouda, Edam and Cheddar cheeses aged to 4 and 15 months, respectively.

Three clusters of consumers were identified based on their flavour liking data. Cluster 1 comprised 34% of the consumer panel and consisted of males over the age of 25 who consumed cheese on a daily basis. These consumers preferred the Cheddar cheeses at four and 15 months respectively. An optimised cheese for this cluster would include attributes of creamy, sour, sweet, slight brothy, Cheddar and prickle flavours. Cluster 2 comprised 50% of the consumer panel and consisted of females between the ages of 19 – 24 who consumed cheese every second day. These consumers liked the flavour of the Gouda, Edam and the two Cheddar cheeses aged to four and 15 months. This cluster did not like the flavour of the Cheddar aged to 32 months. An optimised cheese for this cluster would therefore not include flavour attributes of caramel sweet, brothy Cheddar and prickle. Cluster 3 preferred the flavours of the Gouda, Edam and Cheddar aged to four months. This group comprised 16% of the consumer panel and consisted of males over the age of 25 who ate Cheddar infrequently. An optimised cheese flavour for this cluster would include creamy, salty and lingering cheese attributes.

From the overall liking results it can be concluded that the consumers in this study liked the Gouda, Edam and Cheddar cheese aged to four months equally. The Cheddar aged to 15 months was less liked and the Cheddar cheeses aged to 8 and 32 months were the two least liked cheeses. The Gouda, Edam and Cheddars aged to 4 and 15 months were characterised by a glossy appearance, buttery and creamy aroma, creamy, sour and sweet flavour and springy, rubbery and creamy textural attributes. The aged Cheddar cheeses were characterised by visible white crystals and moisture seepage on the surface, brothy and Cheddar aromas, caramel sweet, brothy, lingering cheese, Cheddar and prickle flavours in conjunction with hard, firm, grainy, crumbly and teeth-coating textural attributes. Female scores followed a similar trend; however, their dislike of the aged 32 month old cheese was apparent. Males indicated a distinct preference for the Gouda cheese followed by the Edam and Cheddar aged to 4 months. Their overall ratings for the aged Cheddar cheeses tended to be slightly higher than those from the female group. PLS results indicated that overall liking was driven by cooked milk aroma, salt content, creamy flavour, glossy appearance and the textural attributes of springiness and creaminess.

Three clusters of consumer were identified based on flavour liking scores. Cluster 1 comprised 35% of the total consumer panel and consisted of females between the ages of 19 – 25 who ate cheese every second day. Their overall liking scores indicated and equal liking of Edam, Gouda and the two Cheddar cheeses aged to four and 15 months respectively. Cluster 2 comprised 30% of the consumer group and consisted of females between the ages 19 – 24 who consumed cheese infrequently. This group preferred the Edam and Gouda cheeses and indicated a distinct dislike of the Cheddar cheeses aged to eight and 32 months. Cluster 3 could not distinguish between the six samples and indicated a liking for all the cheeses. This group comprised 35% of the consumer group and consisted of males over the age of 25 who consumed cheese on a daily basis.

The above-mentioned results confirm that cheese flavour can be optimised to improve consumer acceptance through the application of combined sensory and consumer analysis techniques, i.e. including multivariate statistical techniques. Further work is recommended to gain a greater understanding of consumer acceptance of cheese and Cheddar cheese.

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CHAPTER 7

GENERAL DISCUSSION AND CONCLUSIONS

This study set out to explore consumer attitudes towards Cheddar cheese and determine the sensory characteristics that drive consumption. Furthermore, the study aimed to identify the sensory attributes that could be optimised to encourage greater consumption of cheese amongst specific consumer segments.

Despite cheese being a healthy and nutritious dietary choice, per captia consumption in South Africa falls below that of European consumers (Cheese SA, 2011). Optimising the sensory characteristics of cheese to ensure greater consumption entails identifying and satisfying consumer sensory requirements. To accomplish this, a combination of sensory and consumer analysis techniques are necessary (McEwan, 1996). However, according to Lahne, Trubeck and Pelchat (2014) sensory studies of traditional products that are locally produced, can present a particular challenge.

This study detailed the sensory attributes and consumer acceptance of six cheese variants, including four Cheddar cheeses differing in maturity. In addition, consumer opinions and attitudes towards cheese were explored through a focus group. Instrumental colour analysis was also investigated.

Partial least squares regression (PLS) was performed on the descriptive sensory and consumer panel data. The success of this technique lies in objectively characterising the sensory attributes of Cheddar cheese by descriptive sensory analysis and relating this data to the preference ratings for the Cheddar cheese obtained from a sample of consumers (Murray and Delahunty, 2000). Since PLS can handle multiple dependent variables in the same model, instrumental measurements of colour and composition were also included in the analysis. Hierarchical cluster analysis performed on the acceptance data determined clusters of consumers with similar acceptance behaviour. Further PLS regression performed on each cluster related the sensory preferences of each cluster to the socio-demographic and attitudinal data collected from the consumer panel. Consequently, areas where Cheddar cheese can be optimised to satisfy specific consumer sensory requirements were identified.

Significant findings from this research include the following:

Consumers prefer the flavour and textural attributes of young cheeses. Results from the consumer panel indicated that consumers preferred the Gouda, Edam and Cheddar cheese at 4 months maturity above the aged Cheddar cheeses. The Gouda, Edam and Cheddar at 4 months were characterised as glossy, with a buttery and creamy aroma; a creamy flavour, salty and slightly sour

taste combined with lingering cheese flavour. Textures were described as creamy, springy and rubbery. Sensory attributes of visible white crystals, moisture seepage, brothy and Cheddar aromas; brothy, Cheddar and prickle flavours together with textural attributes of firm, hard, crumbly, grainy and teeth-coating were rejected by consumers. These attributes characterised the aged Cheddar cheeses at 8 and 32 months.

Selection and purchase of cheese is driven primarily by flavour. Price and convenience are important, albeit secondary considerations. Fat content, nutritional offering and brand do not play a critical role in the purchase decision of cheese.

Glossy appearance, a red hue and yellow colour drive cheese colour liking. Texture liking is driven by springy and hard attributes. Flavour liking is driven by cooked milk, buttery and creamy aroma and creamy flavour. Finally overall cheese liking is driven by glossy appearance; cooked milk, buttery and creamy aroma; creamy flavour; springy and creamy texture; fat, moisture and salt content. Overall cheese liking is furthermore driven by yellow colour ($b^* = 42.32$) followed by red hue ($a^* = 16.00$) and finally by luminosity or whiteness ($L^* = 75.68$).

The above-mentioned results are in accordance with that of a recent study conducted where 187 European consumers gave high hedonic ratings to a young Cheddar cheese that was described by the consumers as being sweet, buttery, bland, and mild (Lahne *et al.*, 2014).

Our study also indicated that cheese consumers are not homogenous in their sensory requirements. Based on sensory preference for colour, texture, flavour and the overall characteristics of cheese, it was determined that clusters of consumers exist with specific attitudes, behaviours and sensory requirements. Furthermore, the flavour and texture of cheese can be optimised to satisfy these sensory requirements. For example three clusters, based on their overall liking of the six cheese samples, were identified. The first cluster comprised 35% of the consumer panel and consisted of females between the ages of 19 – 24. This group preferred the flavours identified in the Gouda, Edam and Cheddar cheeses aged to 4 and 15 months. Price, nutritional offering and fat content influenced purchase intent. Cluster 2, comprised 30% of the consumer panel and also consisted of females between the ages of 19 – 24. This group too preferred the flavours identified in the Edam and Gouda, however, they indicated a distinct dislike of the Cheddar cheeses aged to 8 and 32 months. Flavour followed by packaging influenced their purchase decision. The final Cluster comprised 35% of the consumer panel and consisted of males over the age of 25. These consumers liked all the cheeses and could not differentiate between the samples.

Compositional factors of moisture content and pH contributed to atypical flavour development in the Cheddars aged to 8 and 15 months respectively. Cheddar at 8 months developed higher intensities of aged flavours and at similar levels to that of the 32 month Cheddar cheese. The low moisture content of this Cheddar cheese is considered a factor in the unexpected enhanced flavour development (Carunchia-Whetstine, Luck, Drake, Foegeding and Gerard, 2007). In

contrast, the Cheddar aged to 15 months displayed slower flavour development with fewer aged flavours and higher intensities of young flavours evident. The low pH of this cheese is believed to have negatively influenced the activity of the ripening enzymes and their subsequent contribution to proteolysis and flavour development (McSweeney, 2007).

The contrasting results of the focus groups opinion regarding cheese preference and consumer panel is noteworthy. Despite Lawless and Heymann (2010) suggesting that a group panel can characteristically encapsulate and reflect the perception of the target market, the differing sensory preferences between the two groups is significant. The consumer panel comprised 115 consumers while the two focus groups comprised eight individuals each. Although both groups consisted of regular cheese consumers, the variance in age groups should be highlighted. Average age in the focus group was 45, while the majority, 62%, of respondents in the consumer panel were between 19 -25 years of age.

Preference for the six samples varied considerably. The focus group members (with an average age of 45) appreciated the 8, 15 and 32 month mature cheeses and described them as having a lingering Cheddar cheese flavour, visible white spots and a crumbly texture. This group allocated the highest score for overall eating quality to the Cheddar aged to 32 months. For the consumer panel with an average age of approximately 22, the results were in stark contrast as the most of the consumers liked the younger cheeses, i.e. Gouda, Edam and Cheddar at 4 months. These cheeses were described by creamy and buttery aroma, creamy flavour and creamy, springy and rubbery texture. The consumer panel did not like the mature Cheddar cheese samples.

This contrast in results may be due to the effects of information and personal context of the consumers who participated in the focus and consumer groups. Lahne *et al.* (2014) reported that under different information conditions, consumers in their study expressed different hedonic liking and different sensory perceptions towards four types of artisanal cheese. Furthermore the authors confirmed that extrinsic product properties and consumer's personal contexts – product information, consumer familiarity and consumer food involvement had a significant influence on consumer liking of the cheese.

Results for colour liking suggest there are factors other than colour that influence consumer preference. Respondents in the consumer panel indicated a definite preference for the colour of the Gouda and at a higher level than the Cheddar cheese aged to 15 months. Instrumental colour values for these two cheeses were the same. Furthermore, consumers indicated different levels of liking for the Cheddar cheeses at 4, 8 and 32 months. Again, instrumental colour values for these three cheeses were the same, yet preference levels differed. Sensory aspects which may influence colour liking include glossy, visible white crystals and moisture seepage. The attribute glossy was at a high level in the Gouda cheese, but absent in the Cheddar cheese samples whereas visible white crystals and moisture seepage were present at high levels in the aged

Cheddar cheeses. In general, male consumer like coloured and uncoloured cheeses equally while female respondents preferred a coloured chees above an uncoloured cheese.

In conclusion, results of this thesis contribute to an existing body of knowledge. Additionally, with the aim of increasing consumer consumption of cheese, these results offer an alternative to traditional grading and market segmentation. Based on the consumer preference for specific sensory characteristics of cheese, consumer segments can be identified and cheese can be optimised to satisfy these sensory requirements. It is, however, recommended that in conducting further work, the consumer panel incorporate a wider age range of participants. An additional recommendation is to incorporate a study of the extrinsic, socially and culturally contingent properties of consumer sensory perception of Cheddar cheese (Lahne *et al.*, 2014) to gain a greater understanding of consumer perception and hedonic responses to the product.

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ADDENDUM

QUESTIONNAIRE: CHEDDAR CHEESE

Judge Nr __

Name						
Contact details	Tel no (H)			Mobile		
Gender	Male			Female		
Indicate your age group	19-24	25-30	31-35	36-45	46-55	55+
How often do you consume cheese?	Every day	Every second day	Once a week	Twice per month	Once a month	

1. YOU HAVE RECEIVED SIX SAMPLES OF CHEESE, 2 GOUDA-LIKE CHEESES AND 4 VARIATIONS OF CHEDDAR CHESSE.
2. PLEASE EVALUATE THE DIFFERENT CHARACTERISTICS OF EACH SAMPLE AS INDICATED ON THE QUESTIONNAIRE.
3. EVALUATE THE SAMPLES IN THE ORDER PRESENTED, FROM LEFT TO RIGHT.
4. PLEASE RINSE YOUR MOUTH WITH WATER BETWEEN TASTING EACH SAMPLE.
5. KINDLY ANSWER THE QUESTIONS BELOW BY MARKING THE BOX THAT BEST DESCRIBES YOUR DEGREE OF LIKING WITH AN X.

1. COLOUR

Look at the samples in front of you and the mark the box that best describes how much you like or dislike the **COLOUR** of each sample.

	Like extremely		Like extremely		Like extremely		Like extremely		Like extremely		Like extremely
	Like very much		Like very much		Like very much		Like very much		Like very much		Like very much
	Like moderately		Like moderately		Like moderately		Like moderately		Like moderately		Like moderately
	Like slightly		Like slightly		Like slightly		Like slightly		Like slightly		Like slightly
	Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike
	Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly
	Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately
	Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much
	Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely

Please turn to page 2

2. TEXTURE

Taste each sample and then mark the box that best describes how much you like or dislike the **<u>TEXTURE</u>** of each sample.

	Like extremely		Like extremely		Like extremely		Like extremely		Like extremely		Like extremely
	Like very much		Like very much		Like very much		Like very much		Like very much		Like very much
	Like moderately		Like moderately		Like moderately		Like moderately		Like moderately		Like moderately
	Like slightly		Like slightly		Like slightly		Like slightly		Like slightly		Like slightly
	Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike
	Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly
	Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately
	Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much
	Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely

3. FLAVOUR

Taste the samples again and mark the box that best describes how much you like or dislike the **<u>FLAVOUR</u>** of each sample.

	Like extremely		Like extremely		Like extremely		Like extremely		Like extremely		Like extremely
	Like very much		Like very much		Like very much		Like very much		Like very much		Like very much
	Like moderately		Like moderately		Like moderately		Like moderately		Like moderately		Like moderately
	Like slightly		Like slightly		Like slightly		Like slightly		Like slightly		Like slightly
	Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike		Neither like nor dislike
	Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly		Dislike slightly
	Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately		Dislike moderately
	Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much		Dislike very much
	Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely		Dislike extremely

Please turn to page 3

OVERALL LIKING

Taste the samples and mark the box that best describes how much you like or dislike the **<u>OVERALL PRODUCT</u>**.

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

	Like extremely
	Like very much
	Like moderately
	Like slightly
	Neither like nor dislike
	Dislike slightly
	Dislike moderately
	Dislike very much
	Dislike extremely

Please turn to page 4

Indicate your *degree of liking* of the following types of CHEESE	
	1___2___3___4___5___6___7___8___9 Dislike extremely Not sure Like extremely
Mild Cheddar	1___2___3___4___5___6___7___8___9
Mature Cheddar	1___2___3___4___5___6___7___8___9
Extra Mature Cheddar	1___2___3___4___5___6___7___8___9
Low Fat Cheddar	1___2___3___4___5___6___7___8___9
Gouda	1___2___3___4___5___6___7___8___9
Mature Gouda	1___2___3___4___5___6___7___8___9
Edam	1___2___3___4___5___6___7___8___9

***How important* are the following aspects when *purchasing Cheddar cheese*?**	
	1___2___3___4___5___6___7___8___9 Not important *Not sure* Extremely important
Purchase price of Cheddar cheese	1___2___3___4___5___6___7___8___9
Nutritional Value of Cheddar cheese	1___2___3___4___5___6___7___8___9
Fat Content of Cheddar cheese	1___2___3___4___5___6___7___8___9
Flavour of Cheddar cheese	1___2___3___4___5___6___7___8___9
Packaging of the Cheddar cheese	1___2___3___4___5___6___7___8___9
Brand of Cheddar cheese	1___2___3___4___5___6___7___8___9
Convenience of eating Cheddar cheese	1___2___3___4___5___6___7___8___9

Indicate how you consume Cheddar cheese	
As a snack	1___2___3___4___5___6___7___8___9 Seldom Often
In a sauce	1___2___3___4___5___6___7___8___9 Seldom Often
In a sandwich	1___2___3___4___5___6___7___8___9 Seldom Often
In a salad	1___2___3___4___5___6___7___8___9 Seldom Often
With savory biscuits	1___2___3___4___5___6___7___8___9 Seldom Often

Brand Awareness	
Are there any other types of Cheddar cheese that you purchase / consume? For example cheese Spread grated cheese, resealable cheese.	
Are there specific Cheddar cheese **brands** that you prefer purchasing? If so, name your favorite Cheddar cheese brands. For example Elite, Bonnita	